OTH-B RADAR

Environmental Impact Analysis Process

Draft Environmental Impact Statement
Proposed
Alaskan Radar System
Over-the-Horizon Backscatter Radar Program
August 1986

DEPARTMENT OF THE AIR FORCE
AIR FORCE SYSTEMS COMMAND
ELECTRONIC SYSTEMS DIVISION

Air Force
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16 JUL 93

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COVER SHEET

(a) Responsible Agency: U.S. Air Force; cooperating agencies: U.S. Bureau of Land Management, U.S. Fish and Wildlife Service.

(b) Proposed Action: Construction and operation of the Alaskan Radar System, an Over-the-Horizon Backscatter (OTH-B) radar system that would be located in southcentral Alaska.

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(d) Designation: Draft Environmental Impact Statement (DEIS)

(e) Abstract: This document describes the probable environmental impacts of constructing and operating a new surveillance and tracking radar that operates in the High-Frequency band of the electromagnetic spectrum. The radar system would consist of two very large transmit antenna arrays, two larger receive antenna arrays, and an operations center located in southcentral Alaska. Five areas were considered for either the transmit arrays or the receive arrays, and one for the operations center. The significance of possible physical and biological impacts would depend on the specific sites selected in these study areas. Grading and borrow requirements, damage to the permafrost and subsequent damage to the terrain, disruption of salmon spawning beds, disturbance of trumpeter swan nesting areas, the collision of birds with the antenna structure and backscreen, and land acquisition are key concerns. Significant economic stimulation of local rural economies would result from ARS construction and operation. Some impact on subsistence activities could occur from alteration of game migration patterns and from increased access to subsistence resources. Electromagnetic interference with telecommunication systems is unlikely. No reliable evidence exists that chronic exposure of humans to the radiofrequency radiation levels outside the exclusion fence surrounding the transmit arrays is likely to be harmful.

(f) Released to the public August 22, 1986. All written comments pertaining to this DEIS must be received by October 6, 1986.

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SUMMARY

DRAFT ENVIRONMENTAL IMPACT STATEMENT
Construction and Operation of the Alaskan OTH-B Radar System

Description of the Action

The Over-the-Horizon Backscatter (OTH-B) radar is a surveillance and tracking radar system that the U.S. Air Force plans to construct and operate at four locations in the United States. The functions of these radar systems are to detect, track, and give early warning of aircraft and cruise missiles approaching North America. Early warning of hostile aircraft approaching North America is critical to the defense of the United States.

The four planned OTH-B systems would establish a surveillance zone around the east, west, and south perimeters of North America. The Alaskan Radar System (ARS) is needed to complete the perimeter coverage of the western and northwestern approaches to North America.

The functional components of the ARS would be geographically separated from one another: Different sites would be required for the transmit and receive antennas; the operations center, which would process radar data, would be separate from both of those sites. Three areas in southcentral Alaska were studied for the receive site, and three areas in the same region were studied for the transmit site. Because one area could be either a transmit site or a receive site, the total number of areas studied was five. Elmendorf Air Force Base, Alaska, is the proposed location of the operations center.

The OTH-B transmitters and receivers use very large fixed antennas. The two antenna arrays and related structures at the transmit site would require a minimum of about 1,300 acres; the two at the receive site would require a minimum of about 1,200 acres. The operations center would be housed in a conventional building of about 33,000 ft^2. Approximately 70 maintenance and security personnel would be required at the transmit site and about 60 at the receive site; about 315 operating personnel would be located at the operations center.

Public Concerns

In conformance with the requirements of the Council on Environmental Quality, the Air Force convened a series of nine scoping meetings in communities near the areas studied and in Anchorage and Fairbanks. Attendees asked many questions about the characteristics and features of the radar system and its construction. At the request of citizens

seeking more information, Air Force personnel have subsequently conducted telephone conversations and held additional meetings. During these various exchanges, concerns were expressed about:

- Electromagnetic interference with various electronic systems, especially with communication and aviation systems
- Environmental impacts, including physical, biological, cultural, and scenic effects
- Impacts on surrounding lands and activities, such as prospecting, hunting, and recreation, especially those resulting from improved access
- Biological effects of radiofrequency radiation (RFR)
- Restrictions on aircraft operations
- Superior alternative surveillance systems
- The use of land already in federal control
- OTH-B as a military target
- Job opportunities for local residents
- Site selection and decision-making processes.

Environmental Effects

Biophysical Effects

The areas studied for the transmit and receive sites are largely spruce forests in discontinuous permafrost zones. Various rivers, lakes, and streams exist within or border the study areas. Three of the study areas (Glennallen, Gulkana, and Tok) are flat to gently sloping, with frequent boggy and wet areas; the other two study areas are located in more rugged, higher terrain. Because of the wetness as well as the likelihood of permafrost in all areas, significant amounts of borrow material might be required. Gravel is plentiful at Tok, scare at Glennallen and Gulkana, and probably available at Paxson East and Indian Creek. The presence of permafrost would require Arctic construction practices, including site preparation work in the winter. Risk of permafrost damage is greatest at the Glennallen and Gulkana study areas.

Land ownership is complex, ranging from federal and state lands to those held by, allotted to, or selected by Native corporations or individuals. In addition to land for the antenna arrays and associated facilities, the project would need land for access roads, which could be as long as 10 miles; for construction staging areas; and for

gravel sources. Land acquisition could be a significant and time-consuming process in certain cases and could alter existing land use patterns.

Wildlife, which is common in all of the study areas, is used for both subsistence and recreation. Large mammals such as moose, caribou, and bear are hunted, and smaller mammals are trapped.

Three of the study areas (Glennallen, Gulkana, and Tok) lie under major bird migratory flyways. A significant portion of the world's trumpeter swan population nests in or near the Glennallen study area, and raptors may breed in the Tok study area. Given the many large birds in these study areas, siting the antenna arrays in them may lead to bird collisions.

Fish are an important local resource for recreation, local subsistence, and commerce, and salmon (a fish protected by the Constitution of Alaska) inhabit the waterways of all five study areas. Possible access routes to sites in the Indian Creek and Paxson East study areas might follow creeks in which salmon are found. Construction in these areas would thus require special precautions to prevent siltation of sensitive salmon waters and disturbance of spawning beds.

Although no threatened or endangered species are thought to inhabit any of the study areas, field surveys may be required to ascertain the presence or absence of one bird species in that category, as well as certain plants that are regarded as sensitive.

Neither water quality nor air quality is expected to be significantly affected if proper measures are followed during construction and operation.

Socioeconomic Effects

The Copper River Valley area, centered on Glennallen, Gakona, and Copper Center, has about 2,000 inhabitants. The Glenn, Richardson, and Tok Cutoff Highways intersect in this area, and the Trans-Alaska Pipeline passes through it. About 1,000 people live in the area around Tok at the junction of the Alaska Highway and the Tok Cutoff. These towns are important centers of the local economies. In contrast, Paxson is a small recreation center located at the junction of the Richardson and Denali Highways. Indian Creek is sparsely inhabited, lying between and at some distance from two small villages, Chistochina and Slana. Employment in these rural areas is often sporadic and seasonal, and many inhabitants rely on subsistence hunting and fishing.

Jobs from ARS construction and operation and secondary benefits from expenditures could be important locally, but the magnitude of the benefit would depend on the amount of local hiring. The impacts could be particularly significant in the smaller villages, where any effect would constitute a large change in the current situation. Siting at Paxson East would double the local population if the entire workforce lived in that area. If the Air Force were to locate both the transmit and receive sites in the Copper River Valley, the combined impacts could be particularly significant for Glennallen.

The proposed project would cause the loss of several thousand acres of land sometimes used for subsistence. In addition, increased access to remote subsistence areas could have a negative impact on the people who rely on such areas.

The decision to encourage or discourage the ARS employees from bringing dependent families into the area could have an impact on the nearest communities. The significance of the impact would depend on a variety of particular circumstances. For example, in some instances, the local economy and supporting infrastructure could be strengthened by the nearby presence of the facility and employees. Under other scenarios, the Air Force could operate the facility autonomously in a remote site with little apparent local impact. On the more adverse side, the project could introduce social or economic imbalances into sensitive community environments.

If the ARS were constructed close to the highway in the Indian Creek study area, the visual impacts might be significant and require mitigation.

Cultural resources exist in and around the study areas, and additional significant resources are likely to be found in all areas. Proper surveys, consultation with Native American groups, and mitigation measures would thus be required.

Radiofrequency Radiation

Detailed calculations were made to estimate the magnitude and distribution of radiofrequency radiation (RFR) from the ARS, and the resulting values were used to estimate the possible effects of RFR. The validity of the computational methods was confirmed by measurements made at the Experimental Radar System (ERS) in Maine. The exclusion fence around the transmit antenna arrays would be located so that the average power density at ground level outside the fence would be well below the levels designated by the American National Standards Institute (ANSI) 1982 standard for both occupational and general public exposure.

Human Health

Because radiation safety is of paramount importance, an in-depth, critical review of the available literature on the biological effects of RFR was carried out. That review does not include any system-specific

information; rather, it addresses the present state of scientific knowledge on the biological effects of RFR in the range from 0 to 300 GHz. The conclusions regarding possible RFR bioeffects of the OTH-B radar were derived from the most pertinent and scientifically significant results.

Epidemiologic studies performed in the United States and other countries have not provided adequate scientific evidence that environmental levels of RFR constitute a hazard to the general population.

Most U.S. experiments with animals that yielded recognizable and repeatable effects of exposure to RFR were performed at incident average power densities of more than about 1 mW/cm^2 (the ANSI standard). Such effects are thermal, in the sense that the RFR energy is absorbed by the organism as widely distributed heat that increases the whole-body temperature, or as internally localized heat that is biologically significant even with functioning natural heat-exchange and thermoregulatory mechanisms operating.

The existence of threshold values of average power density has been experimentally demonstrated for some effects and postulated for others. Exposure to RFR at average power densities exceeding the threshold for a specific effect for durations of a few minutes to a few hours (depending on the value) may or may not cause irreversible tissue alterations. The heat produced by indefinitely long or chronic exposures at power densities well below the threshold is not accumulated because its rate of production is readily compensated for by heat-exchange processes or thermoregulation.

Most investigations involving chronic exposures of mammals indicated either that no effects occurred or that reversible, noncumulative behavioral or physiological effects took place for average power densities exceeding 1 mW/cm^2. In the few cases in which irreversible adverse effects of exposure were found, such effects were absent for average power densities below 1 mW/cm^2. In a relatively small number of investigations, biological effects of RFR were reported at incident average power densities of less than about 1 mW/cm^2.

In sum, the review of the relevant literature indicates that no reliable scientific evidence exists to suggest that chronic exposure to RFR from the OTH-B radar outside the exclusion fence would be deleterious to the health of even the most susceptible members of the population such as the unborn, infirm, or aged.

Electromagnetic Interference and Hazard Effects

The ARS transmitters would operate from 5 to 28 MHz, which is within what is commonly called the high-frequency (HF) band. Users of the HF band communicate between points as far away from each other as the opposite sides of the earth. The band as a whole is shared by other OTH-B radars, air-to-ground and ship-to-shore communications, standard time and frequency broadcasts, the Amateur Radio Service, Citizens' Band

radio, and others. The specific portions of the HF band within which the ARS would transmit are also occupied by the Fixed Service (set aside for point-to-point communication between non-mobile stations) and the Broadcast Service (international radio broadcasting stations such as the Voice of America).

The radar can operate on a large number of channels. Its frequency use cannot be predicted exactly, however, because it will depend not only on changing ionospheric conditions, but on the frequencies independently used by other occupants of these bands--frequencies that the radar would attempt to avoid. If the radar were operated on a frequency already occupied, it could interfere with reception at distant receivers. Operation of the ERS for approximately 1 year, however, resulted in no valid reports of interference from either Fixed-Service stations or from listeners on the international broadcast bands.

The radar's modulation has been carefully designed so as not to interfere with reception in the adjacent bands. Occupants of these adjacent bands include the Amateur Radio Service, the Maritime Mobile and Aeronautical Mobile Services, standard time and frequency services, and, when the radar is in the Fixed-Service bands, the Broadcast Service. The radar would be operated sufficiently far from the band edges so as not to produce adjacent-channel interference.

The radar would also radiate low-power harmonics of its fundamental frequencies that could interfere with systems using those frequencies. The harmonics would typically not propagate by sky wave to distant regions; thus, any interference effects would be strictly local. Harmonic interference would result from transmission only on particular frequencies. Among the systems considered for potential interference from the radar's harmonics were television, land-mobile radio, air-to-ground radio, and very high frequency (VHF) omnirange (VOR) air navigation beacons.

All study areas are beyond the main service areas of any major television broadcast stations. Television service for some areas is probably provided by the Entertainment Television Project. If interference with television reception were to occur, the radar could avoid the offending frequencies. Measurements in Maine near the ERS showed that at distances of 6 miles or more from the radar, the radar's harmonics that could potentially interfere with television were generally so weak that they were not detectable above the background radio noise.

Measurements and experience at the ERS suggested that harmonic interference with low-band VHF land mobile radio was unlikely at distances greater than about 3 or 4 miles, and a similar prediction applies for the ARS.

Although the VHF air-mobile communication frequencies may be susceptible to harmonic interference, no complaints were voiced during the more than one year that the ERS was operated.

VORTAC and nondirectional beacon ground stations are within a very few miles of the Glennallen and Gulkana study areas; established air routes pass over or close to all of the study areas. Aircraft using VORTACs would sometimes be illuminated by the ARS, and their VOR receivers are potentially susceptible to harmonic interference. Measurements at the ERS indicate that the interference may become severe when the aircraft are within about 30 miles of the front of the transmit arrays. However, those harmonic interference problems result from operation of the radar only on certain frequencies, which can be determined. The Air Force would cooperate with the Federal Aviation Administration (FAA) to determine whether interference exists and to resolve any interference problems.

Aircraft use directional antennas to receive the signal from nondirectional radio beacons and to determine the direction to the beacon. No experimental information is available to judge whether the OTH-B signal would interfere with aircraft reception of a beacon signal.

Operation of the ARS radar is not expected to interfere with reception of broadcast radio beyond a few miles from the transmit site.

The Air Force has developed an "Operational Plan for RF Interference Avoidance" for the OTH-B radars. This plan contains detailed operational procedures to be followed when changing frequencies to avoid producing interference to other users of the radio spectrum. It also contains procedures for cooperative remedial action that the radar operators are to follow when receiving a complaint that the radar has produced interference or is currently doing so.

The ARS would not be a threat to fuel-handling operations, nor would it constitute a threat to cardiac pacemaker owners outside the exclusion fence.

Some electroexplosive devices (EEDs), such as electrical blasting caps, could be detonated by electromagnetic energy. Safe separation distances depend on the electrical conductivity of the ground. They cannot be determined with certainty until measurements of this parameter are made. Estimates indicate that the storage or transport of EEDs would be safe outside the exclusion fence if they were enclosed in metal containers. Otherwise, the safe distance would be about 3 miles in front of the transmit arrays and about 3,000 ft behind them. The use or handling of blasting caps in preparation for blasting operations would be safe if it were done at least 6 miles from the front of the transmit arrays, depending on ground conductivity.

Alternatives Considered

No Action or Postponement of Action

Under this alternative, the ARS would not be constructed and operated on any combination of the study areas, or it would be postponed to allow resolution of specific problems or issues related to these

activities. Because the mission requirement would not be satisfied, the Air Force would continue to study the need for and methods to achieve the mission.

Other Surveillance Systems

Under this alternative, airborne or satellite surveillance systems would be used in place of the ARS. However, airborne systems are prohibitively expensive, and satellite systems require additional development.

Other Locations

No alternative locations to those identified as study areas have been considered. Operational requirements defined an optimal siting region. Additional operational criteria identified the EIS study areas and excluded the remaining portion of the siting region.

Conclusion

Significant long-term biological and physical impacts from the construction and operation of the ARS are possible, but their occurrence depends on the specific sites selected. Carefully planned and executed mitigation measures would reduce the likelihood and severity of potential problems. Selection of less favorable sites would result in significant impacts or require major mitigation measures. Because of the sparse population in the areas studied, significant socioeconomic impacts would occur. The magnitude of these impacts would depend on the study area and the manner in which the project was implemented. To complete the assessment of potential impacts, the Air Force would prepare an environmental assessment after the transmit and receive sites were selected.

GLOSSARY

Abbreviations and Units of Measure

A	Ampere
AAC	Alaskan Air Command
AAC	Alaska Administrative Code
AAMI	Association for the Advancement of Medical Instrumentation
A,B,C,D,E,F	Designations of the six frequency bands of an OTH-B radar, beginning with the lowest frequency
ac	Acre
AC	Alternating current (generally refers to 60-Hz electrical power)
ACGIH	American Conference of Governmental Industrial Hygienists
ACHP	Advisory Council on Historic Preservation
ADF&G	Alaska Department of Fish & Game
ADL	State of Alaska, Department of Natural Resources, Division of Lands
ADNR	Alaska Department of Natural Resources
ADOT	Alaska Department of Transportation
AFB	Air Force Base
AFR	Air Force Regulation
AFSC	Air Force Systems Command
AFOSH	Air Force Occupational Safety and Health

AK	Alaska
AM	Amplitude modulation; the alteration of the intensity of a radio signal to encode sound or data
ANGTS	Alaska Natural Gas Transportation System
AN/FPS-118	Military designation of current OTH-B radar system
AP&T	Alaska Power & Telephone
ARR	Alaska Railroad
ARS	Alaskan Radar System
A.S.	Alaska Statute
ATV	All terrain vehicle
avg.	Average
AWACS	Airborne Warning and Control Systems
bd. ft.	Board feet
BBB	Blood-brain barrier
BBC	British Broadcasting Corporation
BIA	U.S. Bureau of Indian Affairs
BLM	U.S. Bureau of Land Management
B.P.	Before present
Btu	British thermal units
C	Celsius; temperature scale where freezing water is 0°C and boiling water is 100°C
cal	Calorie
CB	Citizens' band (radio)
CCIR	Consultative Committee for International Radio
cfs	Cubic feet per second
cm	Centimeters

CNS	Central nervous system
CO_2	Carbon dioxide
CO	Carbon monoxide
CTP	Chistochina Trading Post
CVEA	Copper Valley Electric Association
CW	Continuous wave
dB	Decibel; ten times the logarithm of a power ratio; a measure of signal strength compared to some reference
dBi	Decibels relative to an isotropic source--one radiating equally in all directions.
dBW	Decibels relative to 1 watt
DC	Direct current
deg	Degree
DGGS	Alaska Division of Geological and Geophysical Surveys
DME	Distance-measuring equipment
DMSO	Dimethyl sulfoxide
DOT	Department of Transportation
DVMT	Daily vehicles miles traveled
E	Electric field intensity--volts per meter
EED	Electroexplosive device
EEG	Electroencephalogram
EIRP	Effective isotropic radiated power; power relative to that radiated equally in all directions by an isotropic source
EIS	Environmental Impact Statement
ELF	Extremely Low Frequency
EMF	Electromagnetic fields

EMI	Electromagnetic interference
EMR	Electromagnetic radiation
EPA	U.S. Environmental Protection Agency
ERS	Experimental Radar System; the precursor to the East Coast Radar System in Maine
eV	Electron volt; a unit of energy
f	Frequency
F	Fahrenheit, conventional temperature scale
FAA	Federal Aviation Agency
FCC	Federal Communications Commission
FDA	Food and Drug Administration
FM	Frequency modulation; the alteration of the frequency of a radio signal to encode sound or data
ft	Feet
FWCA	Fish and Wildlife Coordination Act
FWS	U.S. Fish and Wildlife Service
g	Gram
gal	Gallon
GHz	Gigahertz; one gigahertz = 1,000,000,000 cycles per second
GMU	Game Management Unit
GPD	Gallons per day
gpm	Gallons per minute
H	Magnetic field intensity
H	Henry
HC	Hydrocarbons
HEW	U.S. Department of Health, Education, and Welfare

HF	High frequency (band); specifically, 3 to 30 MHz
hr	Hour
Hz	Hertz; one Hertz = 1 cycle per second
in.	Inches
IRAC	Interdepartment Radio Advisory Committee
IRPA	International Radiation Protection Association
kg	Kilogram
kHz	Kilohertz; one kilohertz = 1,000 cycles per second
kn	Knots
kW	Kilowatt; one thousand watts
lb	Pound
LORAN	Long Range Navigation
m	Meter; one meter = 39.37 in.
MAC	Maximum allowable concentration
MARS	Military Affiliate Radio System
mg/l	Milligrams per liter
μg	Microgram
$\mu g/m^3$	Micrograms per cubic meter; a measure of concentration
μmhos	Micromhos; unit of conductivity
MHz	Megahertz; one megahertz = 1,000,000 cycles per second
mi	Mile
MITRE	The MITRE Corporation; an Air Force contractor
min	Minute
mm	Millimeter
MSL	Mean sea level
mW	Milliwatt; one thousandth of a watt

MW	Megawatt; one million watts
mW/cm^2	Power density in milliwatts per square centimeter
mV	Millivolt; one thousandth of a volt
NDB	Non-directional beacon
NEPA	National Environmental Policy Act
NIEMR	Nonionizing electromagnetic radiation
NIOSH	National Institute for Occupational Safety and Health
nm	Nautical mile; 1 nm = 1.15 mi
NMHC	Non-methane hydrocarbons
No.	Number
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NOSC	Naval Ocean Systems Center
NOTAM	Notice to Airmen
Np	Neper; a unit of attenuation of radio signal intensity
NTIA	National Telecommunications and Information Administration
OTH-B	Over-the-Horizon Backscatter (radar)
OTP	Office of Telecommunications Policy
PAVE PAWS	An Air Force microwave radar system
PEL	Permissible exposure limit
pH	A measure of acidity; pH 7 is neutral
PHS	U.S. Public Health Service
POL	Petroleum, Oil, and Lubricants
PLI	Paxson Lodge, Inc.
ppm	Parts per million

pps	Pulses per second
PMS	Planning Model Study
PRF	Pulse repetition frequency
Quad	Quadrangle
R	Range; a subdivision in the east-west direction used on USGS maps (also see township)
$1/R^2;1/R^4$	One divided by the square or fourth power of the distance; a measure of how much the power density changes with distance. That is, at a distance of 5 units from a source, the power density would be 1/25 that at the source; at 10 units it would be 1/100.
RCRA	Resource Conservation and Recovery Act
RF	Radiofrequency
RFEM	Radiofrequency electromagnetic (fields)
RFR	Radiofrequency radiation
ROW	Right-of-way
s	Seconds
SAR	Specific absorption rate
SFA	Sport Fishing Area
SIRTS	Southern Interior Regional Transportation Study
S/m	Siemens (unit of conductivity) per meter
SO_2	Sulfur dioxide
SPCC	Spill Prevention Control and Countermeasure (Plan)
SWBC	Short-wave broadcast bands
T	Township; a subdivision of land in the north-south direction used on USGS maps (also see range)
TACAN	Tactical Air Navigation System
THC	Total hydrocarbons

TLV	Threshold limit value
tpy	Tons per year
TSP	Total suspended particulates
TV	Television
UBC	Uniform Building Code
UHF	Ultra High Frequency (band); specifically 300 MHz to 3 GHz. Includes TV channels above Channel 13.
USAF	U.S. Air Force
USAFSAM	U.S. Air Force School of Aerospace Medicine
USC	U.S. Code
USDOI	U.S. Department of the Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
V	Volt
VHF	Very high frequency (band); specifically 30 to 300 MHz. The VHF band includes TV channels 2-13.
V/m	Volts per meter; electric field strength
VOC	Volatile organic compounds
VOR	VHF omnirange beacon
VORTAC	A VHF omnirange beacon colocated with a Tactical Air Navigation System
VRM	Visual Resource Management
W	Watts
WHO	World Health Organization
w/kg	Watts per kilogram
WRF	Waveform repetition frequency
yr	Year

Definitions

Active Layer	Layer of ground above the permafrost which thaws in the summer and freezes in the winter
Aeromagnetic survey	A survey of the earth's magnetic field made with an airborne magnetometer
Alkalinity	A measure of the concentration of carbonates, bicarbonates, and hydroxides in water; the opposite of acidity
Alluvium	A general term for clay, silt, sand, gravel, or similar loose rock fragments deposited during relatively recent geologic time by a stream or other body of running water.
Anadromous	Fish, such as salmon and steelhead trout, that ascend freshwater streams from the sea to spawn
Annular	Ring-shaped
Anoxic	Lacking oxygen
Aperture	An opening through which energy enters or exits
Aquifer	A saturated permeable geologic unit that can hold significant quantities of water
Archaeological	Relating to the study of material remains (fossil relics, artifacts, monuments) of past human life and activities
Atria	Main chamber of an auricle of the heart
Avifauna	A collective term for birds
Azimuth	Horizontal angular measure of direction
Benthic	Plants and animals living on or closely associated with the bottom of a water body
Bifaces	Stone tools with edges that are chipped on both sides
Blood-brain barrier	A sack which separates the fluids in the brain from the rest of the body

Boreal	Pertains to the zone of softwood tree vegetation located in the northern and mountainous parts of the northern hemisphere
Boresight	The specific direction in which an OTH-B antenna array is pointed or aimed
Borrow	Gravel material, usually unprocessed, that is used as fill material for construction earthwork
Bradycardia	Relatively slow heart action
Browse	To feed on the tender shoots, twigs, and leaves of trees and shrubs
Calorimetry	Measurement of heat production
Cardiac pacemaker	An electric device that artificially stimulates the heart to beat
Cataractogeneous	Causing cataracts in the eye
Cellular suspensions	A well-mixed liquid containing small biological particles or cells
Chironomic	Larvae of the midge, a two-winged, gnat-like insect
Circadian rhythm	The daily biological cycle of about 24 hours
Closure	The procedure by which a landfill is covered, normally by impermeable material.
Community	Group of populations of plants and animals in a given place
Conductivity, ground	Measure of how easily electric current can pass through the earth; depends on moisture and amount of salts; the unit of conductivity is the siemen
Connate	Refers to water that is as old as the rock formation containing it
Culvert	A pipe which channels water runoff
Detrital	Fragments of material produced by disintegration

Diathermy	Production of heat in tissue by radiofrequency for medical treatment
Dielectric constant	Property of a material, which is not electrically conducting, to be affected by electric fields
Dipole	An antenna having two rods or elements of equal length pointing in opposite directions
Electric vector	The direction of an electric field force
Electroexplosive device	A device such as a blasting cap for detonating explosives
Electromagnetic	Pertaining to electric and magnetic fields
Electromagnetic radiation	Energy propagated as oscillating electric and magnetic fields
Emergent vegetation	Vegetation that may be temporarily to permanently flooded at the base but does not tolerate prolonged flooding
Endangered (species)	On the verge of extinction
Endocrine	Hormone-secreting
Endocrinology	Study of endocrine glands and their secretions; science of hormones
Ephemeral ponds	Ponds which last only a short time
Ephemeropterans	Mayflies, an order of insects
Epidemiology	Study of factors, such as disease, affecting large numbers of persons
Ethnohistoric	Refers to the interpretation of the significance of archaelogical findings by means of documentary material
Far-field	A region remote from an electromagnetic source
Firn	A material that is transitional between snow and glacier ice, being older and denser than snow but not yet glacier ice; snow becomes firn after existing through one summer melt season

Fluvial	Related to or produced by a river
Galactic noise	Radiofrequency radiation coming from the sun and stars that may be detected by radio receivers; extraterrestrial static
Glaciated	To be covered with a glacier
Gneiss	A crystalline metamorphic rock with strongly developed mineral banding
Granitic	A term applied to any light-colored, coarse-grained igneous rock thought to be related to granite
Ground wave	An electromagnetic field propagated along near the surface of the ground
Groundscreen	A wire mesh lying on or near the ground that forms part of the antenna system
Habitat	The place normally occupied by a particular organism or population
Handy-talkie	A compact, easily transportable, battery operated, radio transmitting and receiving set
Hardness	Property of water related to the presence of calcium and magnesium (and also heavy metals); hard water leaves films and residues
Herbaceous	Related to seed plants whose stems wither after each growth season
Histopathology	Study of diseased or damaged tissue
Holocene	Geologic epoch which began 10,000 years ago
Hydrocarbon	A chemical compound consisting solely of carbon and hydrogen
Hydrology	A science dealing with the properties, distribution, and circulation of water on the surface or in the soil and underlying rocks
Hypothalamus gland	Part of the brain which secretes hormones and regulates temperature and metabolism

Igneous	A rock or mineral that solidified from molten or partly molten material.
In vivo	A biochemical process carried out in a living system as opposed to being carried out in a test tube
Ionizing radiation	Energy emissions, such as ultraviolet light, x-rays, and emissions from radioactive materials, that can cause chemical species to break down into ions
Ionosphere	Region of the earth's atmosphere, beginning at an altitude of about 30 miles and extending 250 miles or more above the surface, where the air molecules exist in layers of electrons and ions (electrically charged atoms or molecules)
Lacustrine	Pertaining to, produced by, or formed in a lake
Lagoon facility	A pond containing raw or partially treated wastewater in which aerobic or anaerobic stabilization occurs
Landfill	A system of trash and garbage disposal in which the waste is buried between layers of earth
Lenticular	Having the shape of a double-convex lens
Linearly polarized plane wave	An electromagnetic wave in which the electric field points in one direction
Lithic flake scatters	Archeological sites consisting of rock fragments resulting from the manufacture or use of stone tools
Loam	A rich, permeable soil of low strength, composed of a mixture of clay, silt, and sand and usually containing some organic matter
Lobe	An electromagnetic beam
Lode	A mineral deposit found within consolidated rock

Loess	A homogeneous, commonly nonstratified, loose, fine-grained blanket deposit of soil consisting predominantly of silt generally believed to be deposited by wind
Lossy	Causing attenuation or dissipation of electrical energy
Macromolecule	A large molecule composed of many atoms; a polymer, e.g., a protein
Main lobe	The main electromagnetic beam from an antenna
Mesic	Plants that require moderate amounts of moisture or habitats that are moderately moist
Mesozoic	An era of geologic time between the Paleozoic and the Cenozoic from about 225 to 65 million years B.P.
Metamorphic	Any rock derived from pre-existing rocks by mineralogical, chemical, or structural processes in response to marked changes in temperature, pressures, stress, or chemical environment
Microtine	A group of rodents which includes lemmings and muskrats
Microwave hearing	A sharp radio pulse that may interact with the body so as to be heard
Mineralized	Saturated or filled with minerals or inorganic compounds
Moraine	A mound or ridge deposited by the action of a glacier
Mound	A pile of earth covering an aboriginal grave
Muskeg	A bog or moist upland with thick layers of decaying vegetation and often covered by moss
Mutagenesis	The causing of mutations or alteration of genetic characteristics
Neonatal	Newly born

Neurasthenic	Relating to an emotional and psychic disorder characterized by impaired functioning in interpersonal relationships and often by fatigue, depression, feelings of inadequacy, headaches, hypersensitivity to sensory stimulation, and psychosomatic symptoms (disturbances of digestion and circulation)
Nonthermal	Not caused by, or not causing, heat
Outwash	Sand and gravel carried by melt from a glacier and deposited beyond the marginal moraine
Paleozoic	The geologic peri[illegible] bet[illegible]en 220 and 600 million years ag[illegible] [illegible]en fish, reptiles, and insects first appe[illegible]ed
Penetration depth	The extent to which energy penetrates
Pennate diatoms	A kind of microscopic algae exhibiting a bilateral shape
Percolation	Passage of liquids through a porous substance
Permafrost	Permanently frozen subsoil
Permeability	Property of soil that permits the passage of water
pH	Symbol for the degree of acidity and alkalinity on a logarithmic scale whose values run from 0 to 14; the value for pure distilled water, 7, represents neutrality; numbers from 7 to 0 indicate increased acidity, and numbers from 7 to 14 indicate increased alkalinity
Physiographic	Pertaining to a region, all parts of which are similar in geologic structure and climate
Physiological	Having to do with biological functions
Placer deposits	A waterborne or glacial deposit of gravel or sand containing such heavy ore minerals as gold, which have been eroded from original bedrock and concentrated as small particles that can be washed out

Plecopterans	Stoneflies, an order of insects
Polarized radiation	An electromagnetic wave in which the fields are aligned in some specific manner
Polypeptides	A polymerized group of amino acids; a small protein
Population	Collection of all individuals of a single species
Precambrian	The earliest period of the earth's history ending 600 million years ago, during which time the crust of the earth was formed and the most primitive life forms appeared
Prolate spheroid	Elongated sphere (e.g., a football shape)
Propagule	A reproductive structure of certain plants
Protohistoric	Refers to the period of time immediately preceding recorded history
Pulse modulation	The encoding of sound or data by systematically turning off and on a radio signal
Quanta	Small quantities or "packets" of energy
Quantum absorption	A situation where energy is absorbed only in discrete "packets" or quanta
Quaternary	Geological time period beginning 2,000,000 years ago and continuing to the present time
Radiofrequency radiation	Electromagnetic energy emitted as waves with frequencies ranging from several hundred kHz to several hundred GHz
Radionavigation system	A means by which radio signals are used to determine position and/or direction for navigation
Raptors	Birds that prey on live animals
Recharge zones	Portions of a drainage basin where water flows into the water table
Resonant	A situation in which waves of energy reinforce one another

Richter scale	A logarithmic scale for measuring the strength of earthquakes
Riparian	Vegetation associated with a river
Runoff	Water which comes to the earth as rain and flows over the land into lakes, rivers, and streams
Saline	Containing dissolved salts
Scarp	A steep slope or cliff extending along the edge of an upland
Scatter	Cultural material such as fire-cracked rocks, pottery sherds, and stone tools
Schist	A crystalline rock that splits easily into slabs
Sedimentary	A rock resulting from the consolidation of loose sediment derived from the mechanical and chemical breakdown of preexisting rocks
Seismology	The study of earthquakes and of the structure of the interior of the earth
Septic tank	A settling tank in which settled sludge is in immediate contact with the wastewater flowing through the tank and the organic solids are decomposed by bacterial action
Seral	Pertaining to a series of temporary communities of plants and animals which occur during a successional sequence until the climax (final stage) is reached
Sinusoid	A smooth, regularly-shaped wave in the form of a sine wave
Sky-wave propagation	Refraction of electromagnetic energy from the ionosphere in a manner which permits the signal to illuminate portions of the earth far beyond the earth's curvature
Sounder	Transmitter and receiver system for measuring characteristics of the ionosphere

Species	A fundamental category or group of organisms that are reproductively isolated from all other such groups
Staging area	An area where migrating birds assemble and prepare for migration
Strand line	A former shore line now elevated above the present water level
Subduction	The process whereby one of the plates which comprises the crust of the earth descends beneath another plate
Symptomatology	Characteristics that exhibit the properties of a disease
Tachycardia	Excessively rapid heart beat
Taiga	Coniferous forests of the far northern regions of the northern hemisphere
Talik	A layer of unfrozen ground between seasonally frozen ground (active layer) and permafrost
Talus	A deposit of rock fragments on a slope below a rock face
Tectonic	Having to do with the deformation of the earth's crust
Teratogenesis	Production of abnormalities in fetuses
Terranes	A term applied to a group of rocks of similar age, origin, or structural style
Tertiary	The first period of the Cenozoic era which began about 66 million years ago, extends to between 1 and 2 million years ago, and consists of five epochs
Thaw lake	A lake formed by localized thawing of permafrost
Thermokarst	Refers to irregular topography in a permafrost region where localized melting of ground ice has occurred

Thermoregulatory system	Physiological system that maintains a body at a particular temperature whatever its environmental temperature
Threatened (species)	On the verge of becoming endangered
Till	Predominantly unsorted and very dense mixture of sand, silt, clay, and gravel deposited directly beneath the glacial ice and not reworked by water
Topography	The configuration of a land surface including its relief and the position of its natural and man-made features
Trichopterans	Caddis flies, an order of insects
Tundra	Treeless area in arctic and alpine regions, supporting either no vegetation or such vegetation types as grass, sedges, forbs, dwarf shrubs, lichens, and mosses
Turbidity	A measure of the lack of clarity in a liquid; depends on the amount of solids or organisms suspended in the liquid
Waste assimilation	The incorporation of waste into ambient water
Water quality	The chemical, physical, and biological characteristics of water with respect to its suitability for a particular purpose
Wetlands	Lands containing much soil moisture, such as tidal flats or swamp
Workability	The relative ease or difficulty in working soil with construction equipment

1 PURPOSE AND :ED FOR ACTION

The Over-the-Horizon Backscatter (OTH-B) radar is a surveillance and tracking radar system that the U.S. Air Force plans to construct and operate in four locations in the United States. The functions of these radar systems are to detect, track, and give early warning of aircraft and cruise missiles approaching North America to the North American Aerospace Defense Command and the National Command Authorities.

Early warning of hostile aircraft approaching North America is critical to the defense of the United States. The OTH-B radar system is able to detect aircraft continuously at any altitude at distances from 500 to 1,800 nautical miles (nm) from the receive site. The range of conventional, microwave radars is limited by the earth's curvature to line-of-sight coverage out to a few hundred miles. This range affords little advance notice of high-speed aircraft flying at low altitudes. The OTH-B system would provide a substantial improvement in warning time.

Collectively, the four OTH-B systems the Air Force plans will establish a surveillance zone surrounding North America, except to the north (see Figure 1-1). The modernized Distant Early Warning (DEW) line--known as the North Warning System--will cover the northern approaches to North America. The subject of this Environmental Impact Statement (EIS), the Alaskan Radar System (ARS), is needed to complement the SEEK IGLOO radars in Alaska and to complete the perimeter coverage of the western and northwestern approaches to North America.

Airborne and satellite surveillance systems are possible alternatives to the OTH-B system. However, the airborne systems are not cost-effective, and satellite systems cannot be built until key technical advances are made--advances that are not expected to be achieved in the foreseeable future. Consequently, constructing and operating the four OTH-B radar systems is clearly needed to meet threats to North America posed by aircraft and cruise missiles.

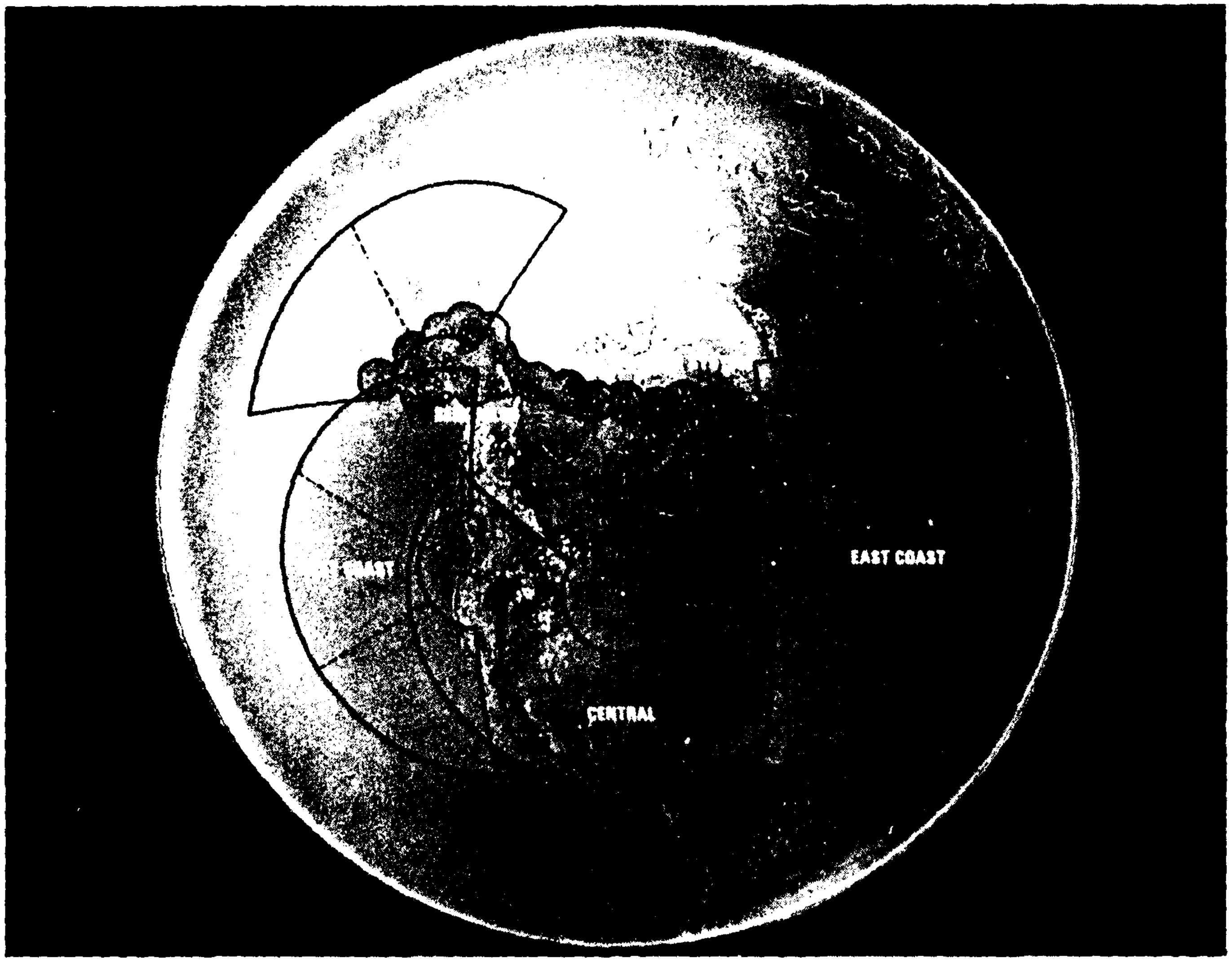


FIGURE 1-1 CONTINENTAL COVERAGE OF OTH-B SYSTEMS

2 PROPOSED ACTION AND ALTERNATIVES

2.1 Proposed Action

2.1.1 The OTH-B Radar System

2.1.1.1 Background and Concept

The proposed action is the construction and operation of an Over-the-Horizon Backscatter (OTH-B) radar system by the U.S. Air Force in Alaska. The purposes of the this OTH-B radar, to be known as the Alaskan Radar System (ARS), are to detect, track, and provide early warning of aircraft and cruise missiles approaching from areas west and northwest of Alaska. This document describes the proposed action, candidate ARS siting areas, and the effects of construction and operation in those areas. Alternative surveillance systems and the alternatives of no action or postponement of action are also discussed.

The proposed system is quite similar to the Experimental Radar System (ERS) that was built and operated in Maine between 1975 and 1981. The ERS has been dismantled, and construction of a production OTH-B system providing 180^{o} of coverage is in its final stages at the same sites. Operation is scheduled for late 1987. Construction of a second OTH-B system on the West Coast began in July 1986. Another OTH-B system is planned for the north central region of the United States and is the subject of a separate EIS. This last system would cover southern approaches to North America and supplement the coverage of the East Coast and West Coast systems.

An OTH-B system differs from conventional, microwave radars in several important respects. Rather than being colocated, the principal system components (i.e., transmit site, receive site, and operations center) are separated by many miles. Instead of one antenna, the system uses many antennas, and instead of being compact, it occupies a large amount of land. In contrast with microwave radars, which radiate power in brief pulses separated by long periods of rest, an OTH-B system radiates continuously. Rather than using frequencies within a relatively narrow band, it uses frequencies chosen from a wide band. Finally, instead of following a straight line to and from the target, the electromagnetic waves from an OTH-B system are bent or refracted by the ionosphere to reach locations beyond the horizon.

Figure 2-1 illustrates the operational concept of an OTH-B system. The surveillance zone (or barrier) created by the radar is a partial ring about 500 nautical miles (nm) wide, beginning 500 to 1,300 nm from

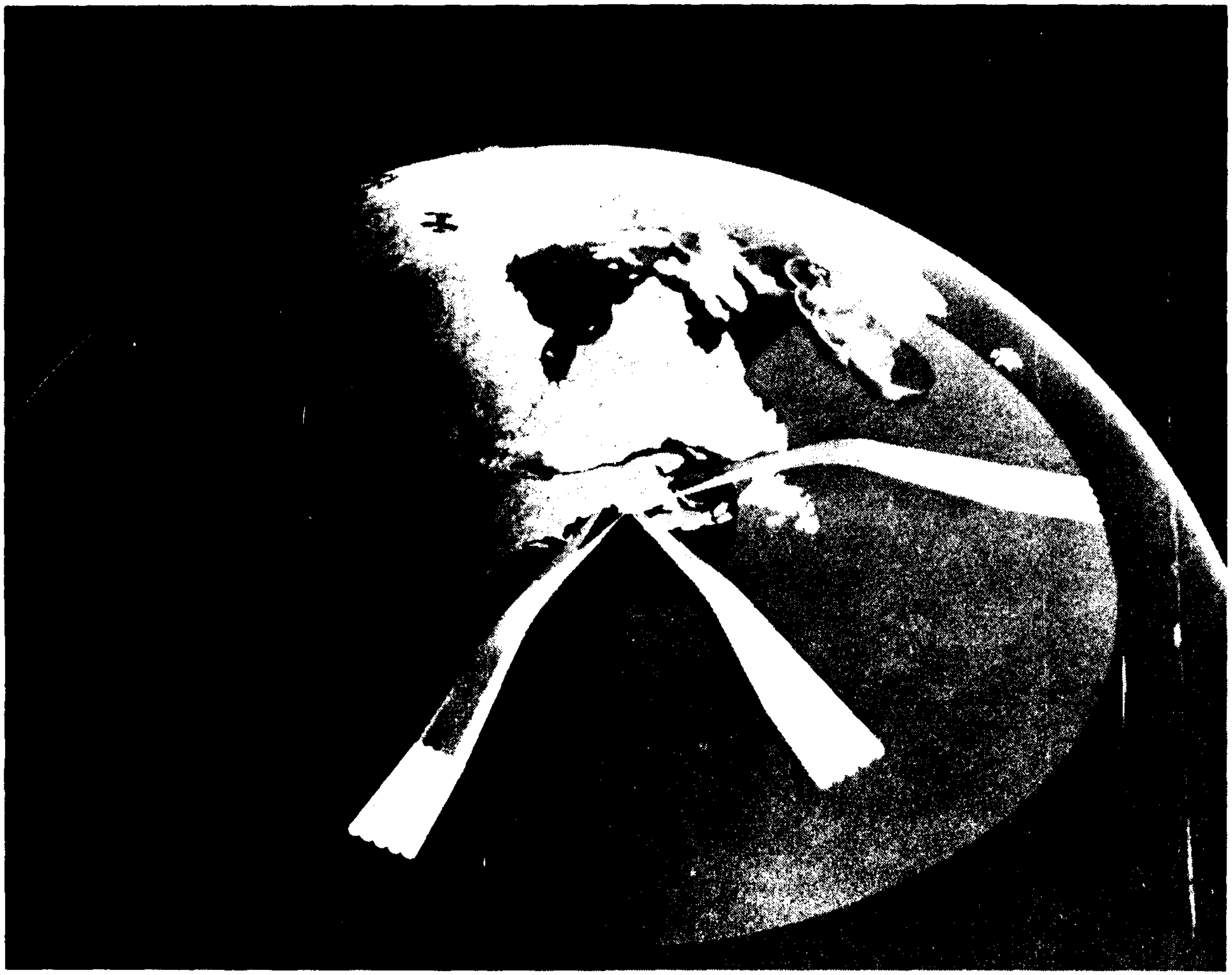


FIGURE 2-1 OPERATIONAL CONCEPT OF OTH-B RADAR SYSTEM

the receive site. The ARS barrier would span a 120° arc, from an azimuth of about 230° (southwest), clockwise, to approximately 350° (north).

The transmit and receive sites must be separated by 50 to 150 nm from one another to prevent the transmitters from interfering with reception of the signal reflected from the target. The operations center should be located at a nearby military installation where the operating staff can be based.

2.1.1.2 Transmit Site

The principal features of an OTH-B transmit site are shown in Figure 2-2, which is a photograph of one of the three East Coast Radar System (ECRS) transmit antenna arrays. The antenna array, which is approximately 4,000 ft long, consists of 6 separate sections, called subarrays, which together span the frequency band from 5 to 28 MHz. Each subarray, in turn, consists of 12 radiating elements. The complete antenna system thus is a linear array of 72 radiating elements mounted on vertical steel towers. The array has a backscreen (behind the array) from 35 to 135 ft tall and a groundscreen (wire mesh on level ground in front of the array) extending out 750 ft. A 15,000-ft^2 building to house the transmit equipment is located behind the array. The building is also used by the staff responsible for operations, equipment maintenance, and site security. The ARS staff would total 70 persons. A wooden (or equivalent non-conducting) exclusion fence surrounds the transmit array, groundscreen, and building. A road outside the fence is used for security patrols. The ARS site would be connected by an access road from the nearest state highway.

To provide the necessary coverage, the ARS transmit site would have two separate fixed antenna arrays oriented 60° from one another. Each transmit array--paired with an array at the receive site--would cover a partial ring 500 to 1,800 nm in range and 60° in azimuth. The two antenna arrays would face west (260° compass direction) and northwest (320°). A representative layout is shown in Figure 2-3. The actual arrangement of the two antenna arrays would depend on terrain and other factors at the selected transmit site, but a minimum of 1,200 acres would be required.

The radar beam produced by each transmit array would be electronically steered in steps of 7.5° (for a total azimuth change of ±30°) by varying the phase (i.e., timing) of the electric current delivered to the radiating elements. Under normal circumstances, the two ARS transmit arrays would radiate simultaneously and cooperatively to maintain the surveillance zone. The wavelengths of the OTH-B radar beam vary from 10.7 to 60 meters (m). These wavelengths are similar to those radiated by radio amateurs and "short wave" radio stations, but are much longer than those of conventional radars, which have wavelengths

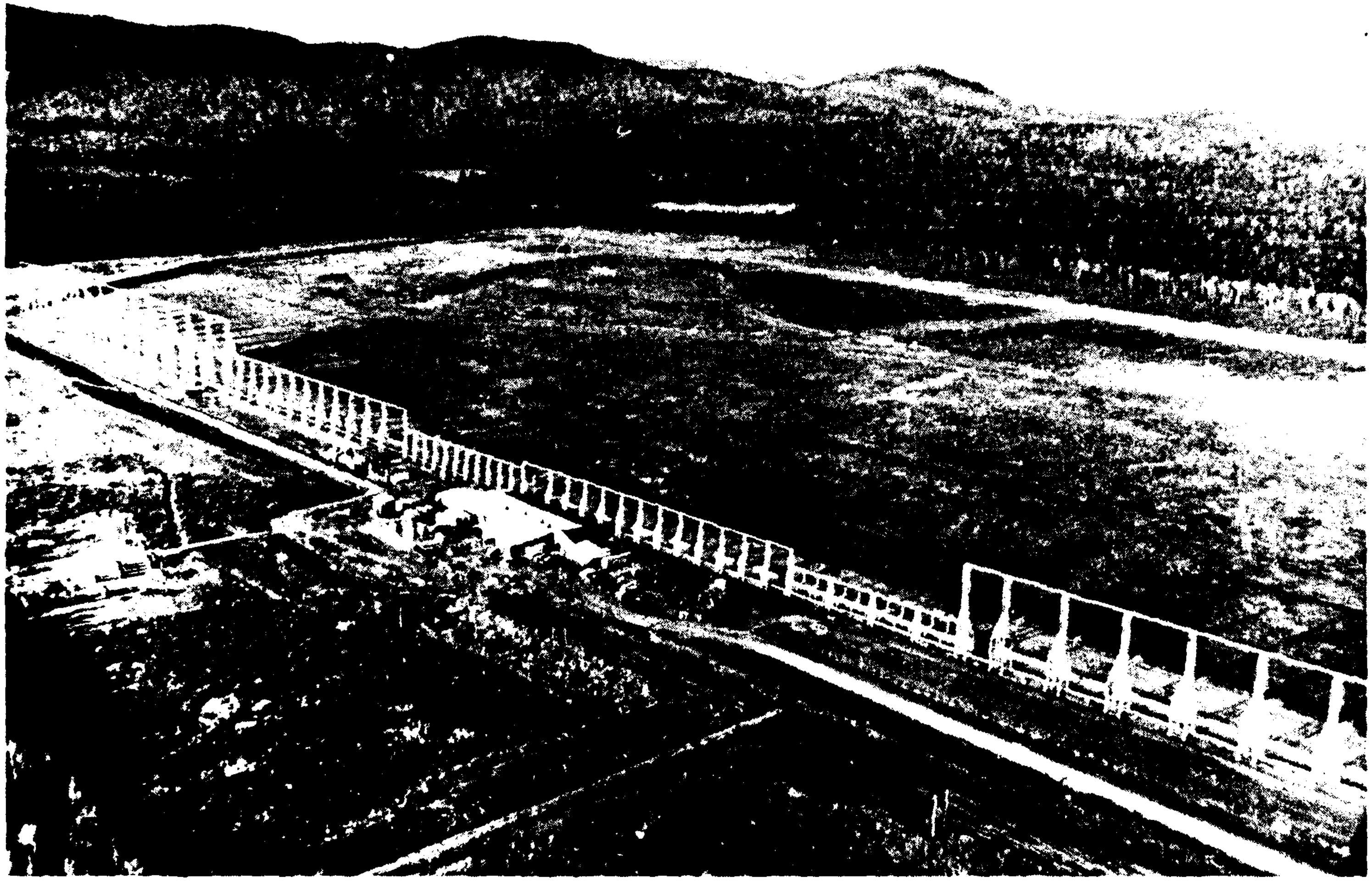


FIGURE 2-2   EAST COAST RADAR SYSTEM TRANSMIT SITE

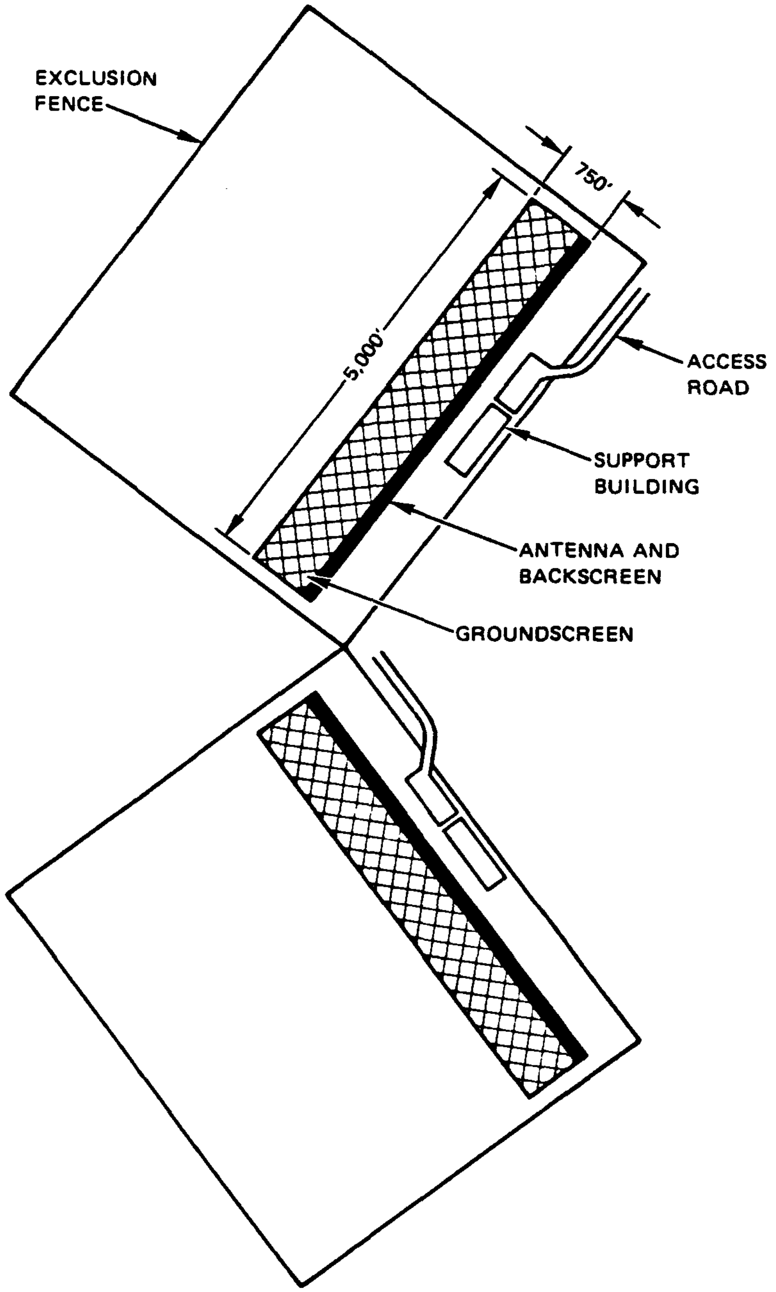


FIGURE 2-3 SCHEMATIC OF REPRESENTATIVE ARS TRANSMIT SITE

from a few centimeters (cm) to about 1 m. Only one subarray of each antenna system would be driven at any one time, and the frequencies radiated from each of the two ARS arrays would usually differ from one another. Further details of the transmit system are contained in Appendix A. The beam would point in a particular direction for a brief interval, which may be as large as 10 seconds. Because 8 steps of 7.5° would be required to cover 60°, as many as 80 seconds could pass before the beam returned to a given direction.

Because only the transmit arrays would radiate electromagnetic energy, there is particular interest in the transmit site and the nature and magnitude of the resulting radiofrequency radiation (RFR). RFR from a transmit array forms a concentrated beam that moves outward and upward from the site. The effective width of the beam is about 8.4°, the effective height about 24°, and the upward or takeoff angle in the range 1° to 25°. When the beam reaches a height of about 50 to 150 miles, it enters a region of the atmosphere called the ionosphere and is refracted (bent) back toward the earth. On reaching the earth, the energy of the incident beam is reflected and scattered again. A small fraction of the reflected beam returns toward the source, again to be refracted by the ionosphere, and reaches one of the receive arrays. Signal processing equipment analyzes the return beam to detect aircraft and cruise missiles.

Most of the power delivered to each transmit array would appear in the main beam and leave the transmit site. However, some energy would be dissipated in other, less powerful beams. These other beams are called backlobes if their general direction is opposite to that of the main beam, or sidelobes if their general direction is the same as that of the main beam. The RFR intensity of the backlobes would be less than one-tenth that of the main beam.

2.1.1.3 Receive Site

The receive site plan would be similar to that of the transmit site. The principal differences would be a longer antenna array (about 9,000 ft), a closer exclusion fence, and the use of only a single subarray with a uniform 65-ft tall backscreen. The exclusion fence would enclose the groundscreen and adjacent support building for security; RFR hazards are not a concern. A plot of land roughly 10,000 ft by 2,600 ft (about 600 acres) would be required for each receive array and exclusion area; thus, the receive site would require a total of at least 1,200 acres. The adjacent buildings would be somewhat smaller than those for the transmit site (5,000 ft^2) because receiving equipment is smaller than high-power transmitters. One building would be used by the staff of approximately 60 to operate and maintain equipment and to provide security. Figure 2-4 is a photograph of one of the ECRS receive arrays.

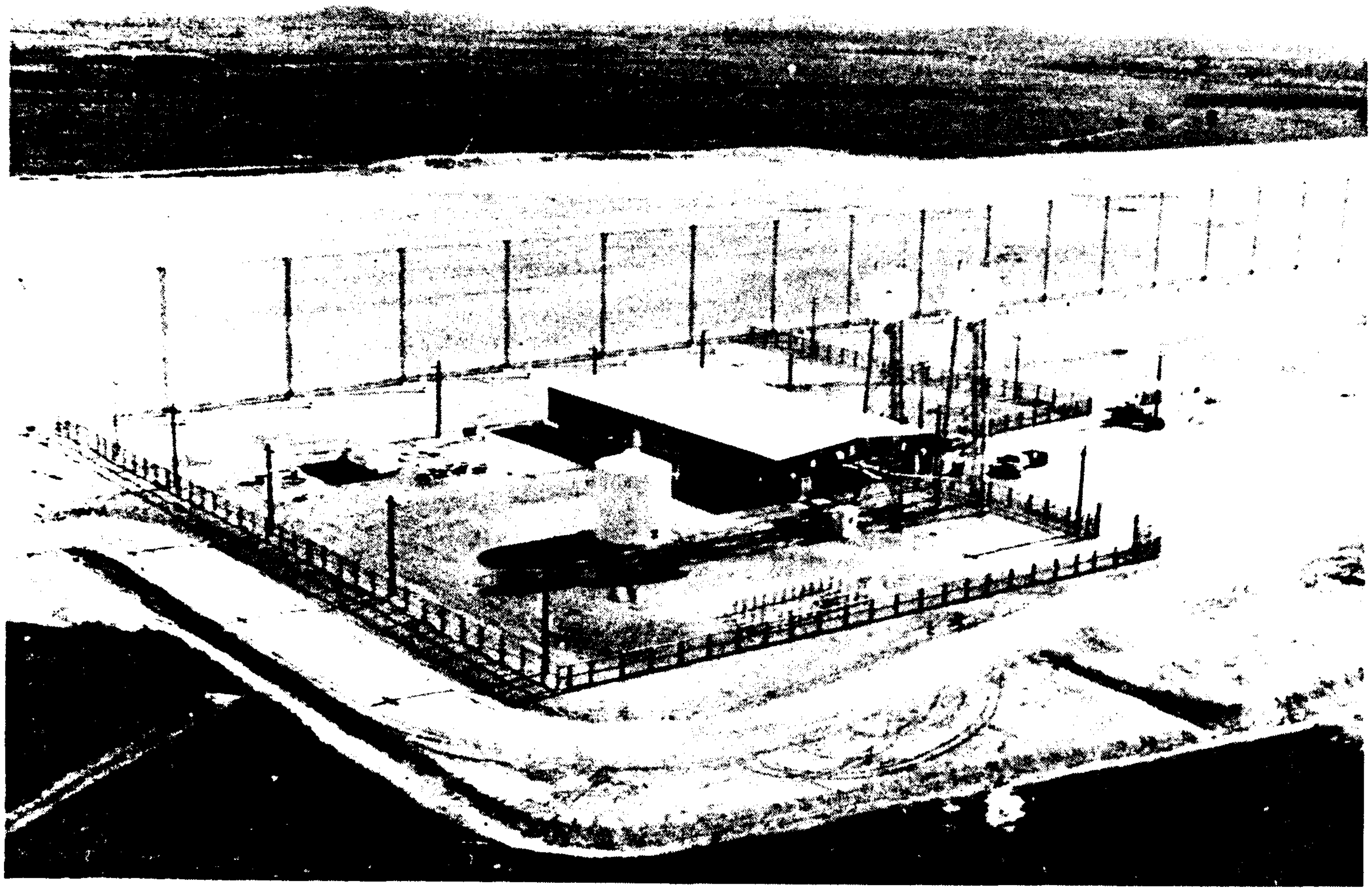


FIGURE 2-4 EAST COAST RADAR SYSTEM RECEIVE SITE

2.1.1.4 Operations Center

The operations center would be a nontransmitting 33,000-ft^2 building for equipment and a staff of about 315 Air Force and contractor personnel. It would control the operation of the transmit and receive arrays. Using data from the transmit and receive sites, the operations center would detect, track, identify, and report all aircraft and cruise missiles within the coverage area.

2.1.1.5 Utilities and Other Facilities

2.1.1.5.1 Electric Power

The transmit site would require approximately 10 MW of electric power. The Air Force would buy from commercial sources if reliable power were available near the selected site. A standby power plant would be built to meet all requirements except those for transmitting. However, the Air Force has determined that the existing electric power net in Alaska is inadequate to meet the Air Force's needs at the transmit site. Therefore, a new power plant would be required. The Air Force would request proposals from private utilities to supply power that meets reliability and other requirements. Would-be suppliers could propose virtually any form of generation on or off the site. If an acceptable proposal was not received, the Air Force would build a power plant itself. In that case, direct-drive diesel generators would most likely be used. This method of generation is also the most likely if a utility supplies the power.

The receive site would require about 2 MW of electric power. At some locations, commercial sources may be adequate to meet the power requirements at the receive site. In those cases, only a standby power plant would be built. If commercial sources were not adequate, the Air Force would build a power plant.

Fuel would be stored at both sites to ensure that it is available even when tanker truck delivery is interrupted. Each above-ground storage tank would be surrounded by lined dikes to control spills. The Air Force would prepare control plans to deal with spills on the site.

2.1.1.5.2 Housing

Living quarters would be provided for 70 people who would work at the transmit site and for 60 who would work at the receive site. If the transmit arrays are built in the Tok area, existing dormitories at a former Army pipeline camp could be renovated. In all other areas, living quarters would be constructed on the site. No accommodations would be provided for families. Although the housing built would be sufficient to accommodate all personnel, they would not be required to live on the site.

2.1.1.5.3 Water, Wastewater, and Solid Waste

Wells or nearby lakes would be used as the permanent source of water at the transmit and receive sites. Approximately 11,000 gallons per day (gpd) would be required at the transmit site and at the receive site. The choice of wastewater system to handle the approximately 10,000 gpd of domestic sewage at each site would be based on local conditions. The options are: a package treatment plant, on-lot disposal and leach fields, and extended aeration with double-lined aerated evaporation lagoons. Waste oil and solvents would be trucked off-site for proper disposal. The Air Force would comply with all applicable federal and state standards.

Solid waste would be trucked to a landfill near the base camp. Combustible materials would first be reduced in an oil-fired incinerator. Any slash generated during construction by the cutting of trees and brush would be chipped for use in leveling, insulating, or covering the ground.

2.1.1.5.4 Communication Systems

Communication systems for the ARS would include telephone lines for administrative and routine operating matters; a classified telephone system; and both classified and unclassified data handling systems. The capacity and design of the communication systems would not be determined until the design for the entire ARS was underway.

Commercial telephone lines and switching networks would be used for routine telephone calls. New telephone lines would be needed only from the transmit and receive sites; the operations center would be located in an area where service is currently provided by commercial telephone companies. A link would be needed to transmit data from the receive systems to the operations center for processing. Three potential methods are under consideration: satellite; radio, either line-of-sight or tropospheric scatter; and land line. The choice would be made after the receive site was selected and engineering and cost studies were carried out.

2.1.1.6 Construction

Construction of the ARS is scheduled to begin in late 1988 and continue into 1992. Construction would be timed so that those activities best done while the ground is frozen would be carried out during the winter. Operation would begin in the mid-1990s.

Construction at both the transmit and receive sites would begin with the establishment of an initial staging area adjacent to the existing primary highway near where the access road to each site would connect with the highway. The staging areas, each about 5 acres in extent, would be used to store the equipment and materials necessary to construct the site access roads. After the access roads were constructed

and the site base camps established, the staging areas would be restored as closely as possible to their original conditions.

The access roads would be 24 ft wide and have 4-ft shoulders. In permafrost areas, the roads would be constructed by filling with gravel and then paving; conventional construction would be used in nonpermafrost areas. The method employed would be determined by the results of soil borings that preceded road construction. The route of the access roads would be selected to limit their effects on drainage and on nearby streams and lakes.

Site base camps would be established at the end of the access roads on land that would be part of the final sites. Approximately 10 acres at each site would be set aside for storage of equipment and materials. Gravel would be taken from nearby sources. Significant quantities of gravel might be required. Therefore, its availability would be a consideration in the selection of a site. Water for construction would be trucked in; bottled water would be provided for human consumption. Portable toilets would be used. Approximately 20,000 gallons of diesel fuel would be stored in tanks surrounded by spill control berms. Temporary living quarters would be provided if housing accommodations in local communities were inadequate.

Grading of site areas other than the antenna array and groundscreen locations would be minimized. In permafrost areas, gravel would be used to establish walkways and roadways. Conventional methods would be used in nonpermafrost areas.

Either backfrozen piles (thermal piles or drilled-and-driven nonthermal piles) or an insulating gravel pad and gravity anchors would be used for the antenna foundations in permafrost areas. The type of pile and the pile configuration would be chosen after the subsurface material and ground temperature were determined. Piers or gravity footings would be used in nonpermafrost areas.

Conventional methods would be used to construct building foundations in nonpermafrost areas. In permafrost areas, buildings, including the power plant, would be elevated above grade on thermal piles, drilled-and-driven piles, or insulating gravel pads and piers.

An OTH-B radar requires a nearly level groundscreen in front of each antenna array. In nonpermafrost areas, the requirement can be met by clearing and grading and cutting and filling as necessary. For permafrost areas, the Air Force is considering four approaches to meeting the requirement:

1. Cutting trees and trimming brush as necessary; mounting the groundscreen on backfrozen posts when necessary to maintain it level.

2. Cutting trees; placing the groundscreen on a gravel pad over undisturbed ground.

3. Combining 1. and 2.

4. Cutting and filling.

The method chosen would depend on the specific conditions at the sites selected, including terrain and the presence of permafrost.

The area from the groundscreen to the exclusion fence must be kept clear of obstructions. The initial clearing would take place during winter months. Only very high brush and tall trees would need to be cut at the snow level. Low growth of vegetation above the groundscreen is acceptable. Additional cutting required by growth over the project life would be carried out as needed, also during winter.

The perimeter road outside the exclusion fence would be constructed in the same manner as the site access road, except that it would not be paved. It would be 12 ft wide with 2-ft shoulders. The fence posts would be drilled and set to backfreeze from equipment operating on the road.

2.1.1.7 <u>Land Acquisition</u>

To construct the ARS, the Air Force must acquire title to or use rights for the necessary land. Acquisition would be as specified in Air Force Regulation (AFR) 87-1, "Acquisition of Real Property" (December 1985).

That regulation states that the Air Force may acquire real property, or the use rights to real property, by any method that satisfies its needs in the most economical manner with the least impact on the local economy. The necessary rights may be acquired through purchase, lease, transfer, exchange, or donation of private land, or through withdrawal of public land. The Air Force prefers, in the following order: permanent acquisition, leasing, or land withdrawal. It would also seek to purchase both surface and subsurface rights, and to restrict the land to Air Force uses.

2.1.1.8 <u>Decommissioning</u>

Current plans call for the ARS to operate continuously for at least 20 years after normal operations begin. Decommissioning would be accomplished in accordance with the applicable laws and regulations at that time. If the land was purchased, it would be made available for other federal use. If the land was leased, it would be disposed of in accordance with the terms of the lease.

Improvements to real property would be left in place or removed, according to the circumstances and the terms of any lease agreement. Any demolition would be carried out in compliance with applicable

federal, state, and local regulations. The sites would be examined under the Department of Defense Installation Restoration Program before disposition to ensure that no contamination problems existed.

2.1.2 Location of the Proposed Action

2.1.2.1 Site Selection Process

Acceptable locations for the ARS were identified by systematic application of various criteria. The first requirement for acceptable site locations was that the necessary radar coverage could be provided. The required coverage was specified by the following operational criteria:

- Begin coverage at the Alaskan coast, overlapping the coverage of coastal radars
- Overlap the coverage of the North Warning System
- Begin southerly coverage at 50° N latitude, 165° W longitude.

Given the minimum and maximum ranges of the OTH-B system, application of these criteria defined the search area outlined in Figure 2-5. This search area is bounded approximately on the north by 64° N latitude, on the west by 150° W latitude, on the south by the Gulf of Alaska, and on the west by the U.S.-Canadian border.

With a search area defined by radar coverage requirements, the next step was to refine the area of interest based on the following operational considerations:

- To limit construction, logistic, and maintenance costs, the transmit and receive sites should be located within about 10 miles of a primary highway or on the coast or an island.
- The visual horizon should be unobstructed above 1° from the horizontal within each 60° field of view for the first 10 miles in front of the antenna arrays, and above 3° beyond 10 miles.

Application of these considerations yielded general locales that appeared to meet the criteria (unshaded portions of Figure 2-6). Within these locales, the following specific areas were further investigated and rejected:

- Kenai Peninsula: sites near Tustumena Lake, north of the Swanson River and north of Anchor Point, suffer from horizon obstructions and conflict with recreational uses.
- Fire Island: electromagnetic interference would disturb existing facilities.

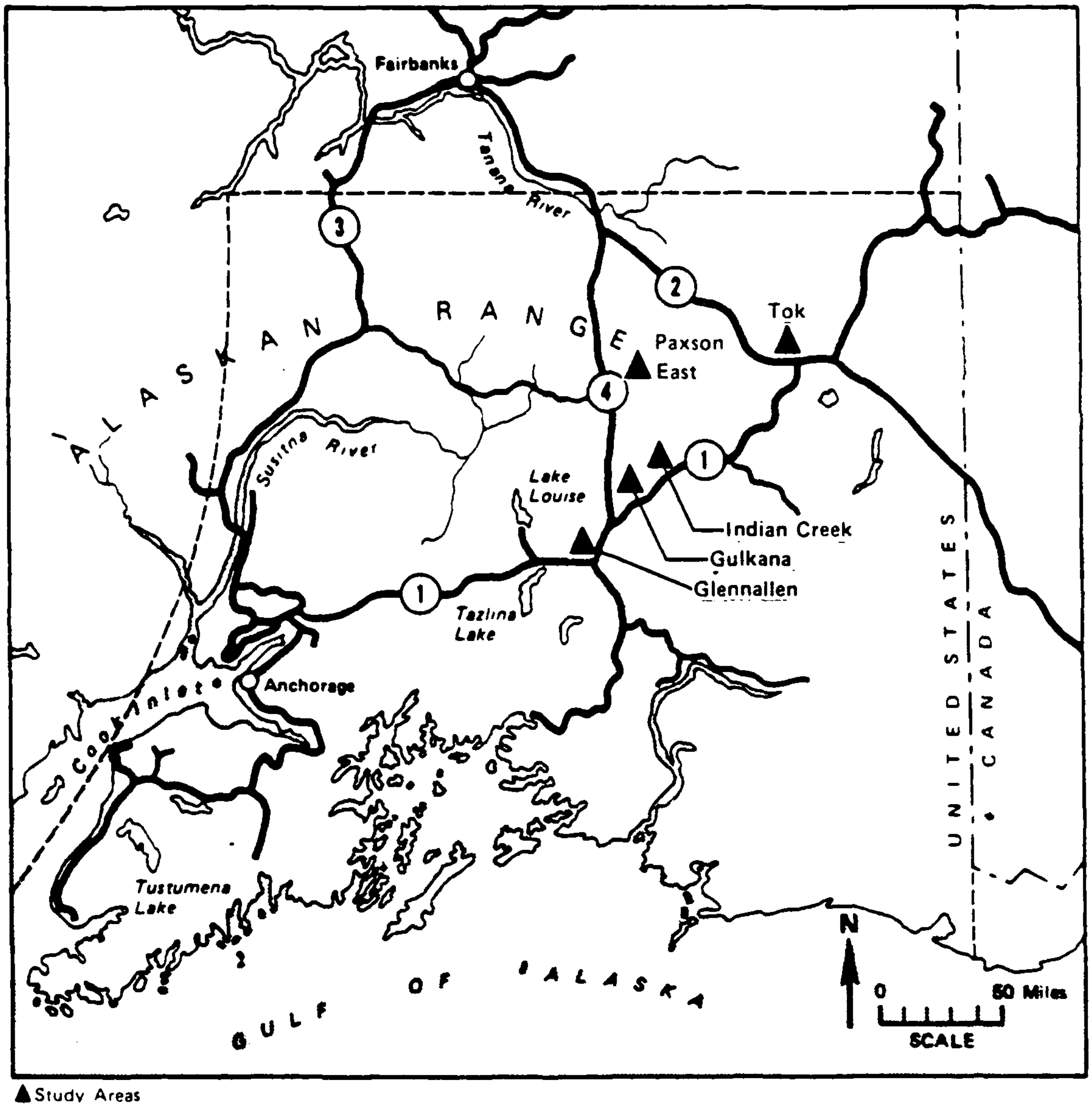
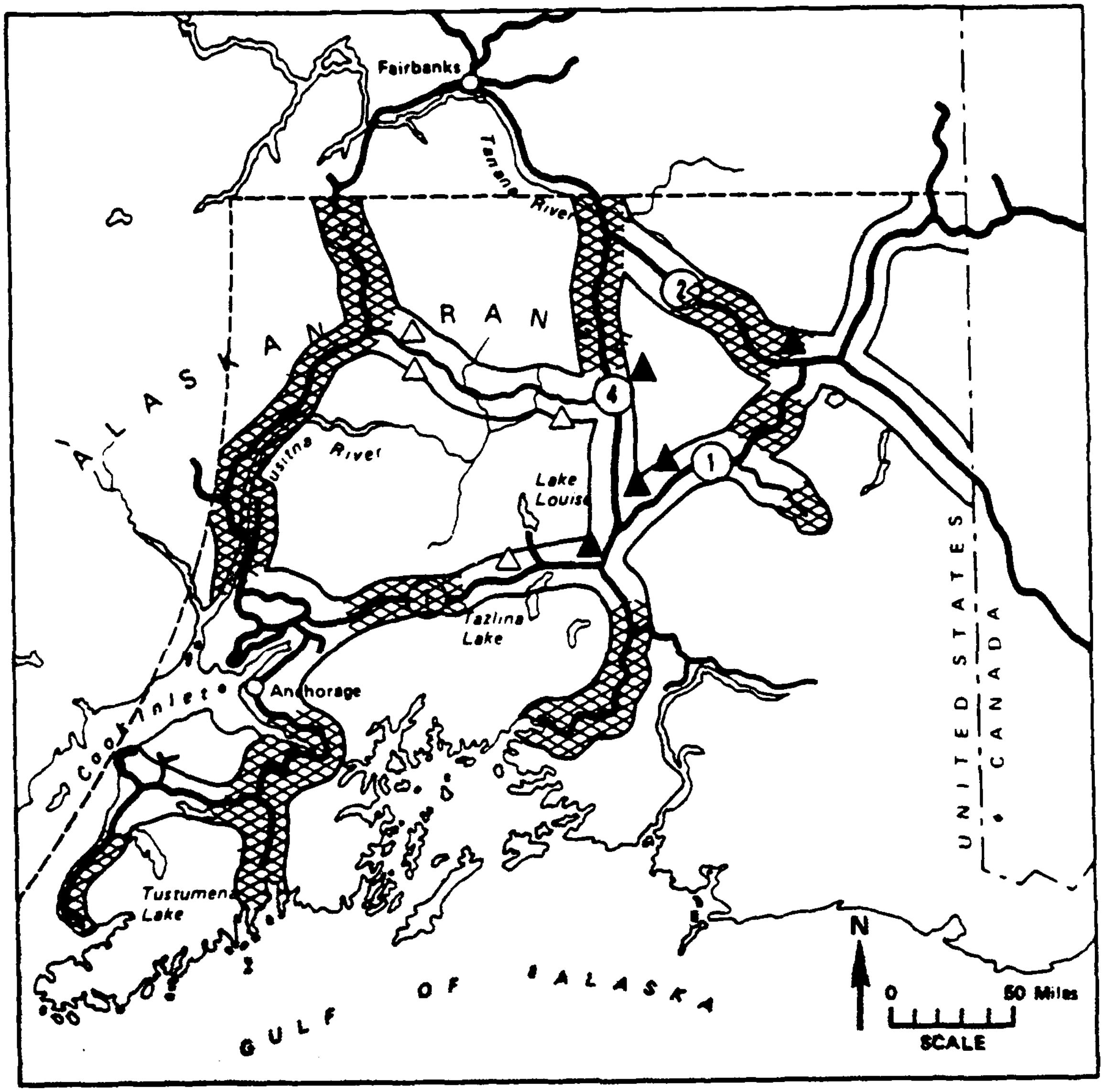


FIGURE 2-5 SITE SEARCH AREA FOR ALASKAN RADAR SYSTEM



Obstructed Areas △ Rejected Areas ▲ Final Study Areas

FIGURE 2-6 STUDY AREA SCREENING

- Islands in Prince William Sound: construction and operating costs would be high because of the need to build port facilities and more infrastructure; some islands have unfavorable terrain that would require extensive earthwork.

- East and south of the Copper River: the cost of bridge construction would be high; impacts would occur from opening the relatively pristine area near the Wrangell-St. Elias National Park.

- Along the Nebesna Road: the terrain is obstructed; land would be difficult to acquire.

- Forty-Mile River area north and west of Tok: the terrain is unsuitable.

- Along the Taylor Highway: the terrain is unsuitable.

The Air Force also specifically investigated military installations in or near the search area for their ability to accommodate either the ARS transmit or receive site. All were rejected because of proximity to sources of electromagnetic interference, incompatibility with existing facilities, unacceptable obstructions, or location outside of the search area:

- Elmendorf AFB and Fort Richardson: they are too close to Anchorage, aircraft activity, and radio facilities.

- Clear Air Force Station: electromagnetic interference with existing systems would occur; it is also outside of the search area.

- Fort Wainwright: it is too near to Fairbanks; it is also outside of the search area.

- Eielson AFB: it is too close to populated areas; it is also outside of the search area.

- Fort Greely: obstructions exist; electromagnetic interference with existing systems would occur.

Two final study area screening criteria that were applied were related to specific features or off-site influences.

- Sufficient land to accommodate two antenna arrays

- Flat terrain or land sloping away in the scan directions.

When applied, these criteria yielded nine study areas. In addition to the five study areas addressed in this EIS, areas known as Brushkana, Monahan Flat, Paxson West, and Slide Mountain were identified (see

Figure 2-6). Subsequent investigation of these areas and comments made at the scoping meetings revealed one or more factors, conditions, or circumstances that made each unacceptable:

- Brushkana: conflict with recreational uses would occur; it is also a caribou area and possibly archaeologically sensitive; many miles of the Denali Highway would have to kept open during winter.

- Monahan Flat: it is a relatively pristine area; the presence of an OTH-B system would have a significant visual impact from the highway; it is a caribou calving area; a long power line would be needed; Denali Highway would have to be kept open.

- Paxson West: it is an area of high recreational use; given the difficult road alignments and very heavy snows, the roads would be difficult to keep clear.

- Slide Mountain: a conflict with existing and planned developments and extensive recreational use would occur; the Nelchina Public Use Area is nearby.

During the period of investigation, the Air Force received a suggestion that a location on the Kenai Peninsula be considered. However, the distance between that location and every other study area exceeded the maximum acceptable separation distance criterion. Land closer to Kenai was tentatively identified at McKenzie Point. However, both locations are close to major sources of electromagnetic interference. In addition, the surveillance coverage provided by a transmit site on that part of the Kenai Peninsula would not meet the criterion that it overlap the North Warning System coverage. Furthermore, the suggested area is adjacent to the Kenai Wildlife Refuge in an area of high recreational use.

2.1.2.2 Study Areas

A study area is a unit of varying size that meets the OTH-B siting criteria. This EIS discusses five study areas for the transmit and receive sites and one proposed site for the operations center. The EIS does not examine specific sites within the study areas.

A study region is a group of one to three study areas, located within a natural geologic-physiographic region, that for the purpose of analyzing certain aspects of the environment possess essentially the same characteristics.

The study regions, study areas, and associated ARS functions are listed in Table 2-1. Figure 2-7 is a regional map showing the five study areas. Maps of the individual study areas are presented in Section 3. The table and maps show precise study area boundaries, but

Table 2-1

ARS STUDY REGIONS AND AREAS

Copper River Valley Region

Glennallen (Receive or Transmit) [Gulkana]*

Township	Range	Sections	
T. 7 N.	R. 3 W.	31-36	Gulkana B-4+
T. 6 N.	R. 3 W.	All	Gulkana B-4
T. 5 N.	R. 3 W.	All	Gulkana A-4
T. 4 N.	R. 3 W.	4-9, 16-21, and 28-33	Gulkana A-4
T. 4 N.	R. 4 W.	All	Gulkana A-4, A-5
T. 5 N.	R. 4 W.	All	Gulkana A-4, A-5
T. 6 N.	R. 4 W.	All	Gulkana B-4, B-5
T. 7 N.	R. 4 W.	31-36	Gulkana B-4, B-5

Gulkana (Receive) [Gulkana]

Township	Range	Sections	
T. 8 N.	R. 1 E.	35 and 36	Gulkana B-3
T. 7 N.	R. 1 W.	13, 14, 23-26, 35, and 36	Gulkana B-3
T. 7 N.	R. 1 E.	1, 2, 9-16, 19-23, and 26-34	Gulkana B-3
T. 6 N.	R. 1 E.	6, 7, and 18	
T. 6 N.	R. 1 W.	1, 2, 12, and 13	Gulkana B-3
T. 8 N.	R. 2 E.	8-10, 15-17, 20-22, 27-29, and 31-34	Gulkana B-3
T. 7 N.	R. 2 E.	3-6	Gulkana B-3

Indian Creek (Receive) [Gulkana]

Township	Range	Sections	
T. 11 N.	R. 4 E.	1, 11-14, and 24	Gulkana C-1, C-2
T. 11 N.	R. 5 E.	4-8, 11-14, 17-20, 23-29, 34, and 35	Gulkana C-1, C-2
T. 12 N.	R. 5 E.	31-33	Gulkana C-1

Table 2-1 (Concluded)

Alaska Range Region

Paxson East (Transmit) [Mt. Hayes]

Township	Range	Sections	
T. 21 S.	R. 12 E.	10-17 and 23-25	Mt. Hayes A-3

Tanana River Region

Tok (Transmit) [Tanacross]

Township	Range	Sections	
T. 19 N.	R. 13 E.	19-36	Tanacross B-4
T. 18 N.	R. 13 E.	1-18, 22-27, and 34-36	Tanacross B-4
T. 18 N.	R. 14 E.	All	Tanacross B-4
T. 17 N.	R. 13 E.	1-3 and 10-15	Tanacross B-4
T. 17 N.	R. 14 E.	4-9 and 16-18	Tanacross B-4

Elmendorf AFB (Operations Center) [Anchorage]

Township	Range	Sections	
T. 13 N.	R. 3 W.	3 and 4	Anchorage A-8

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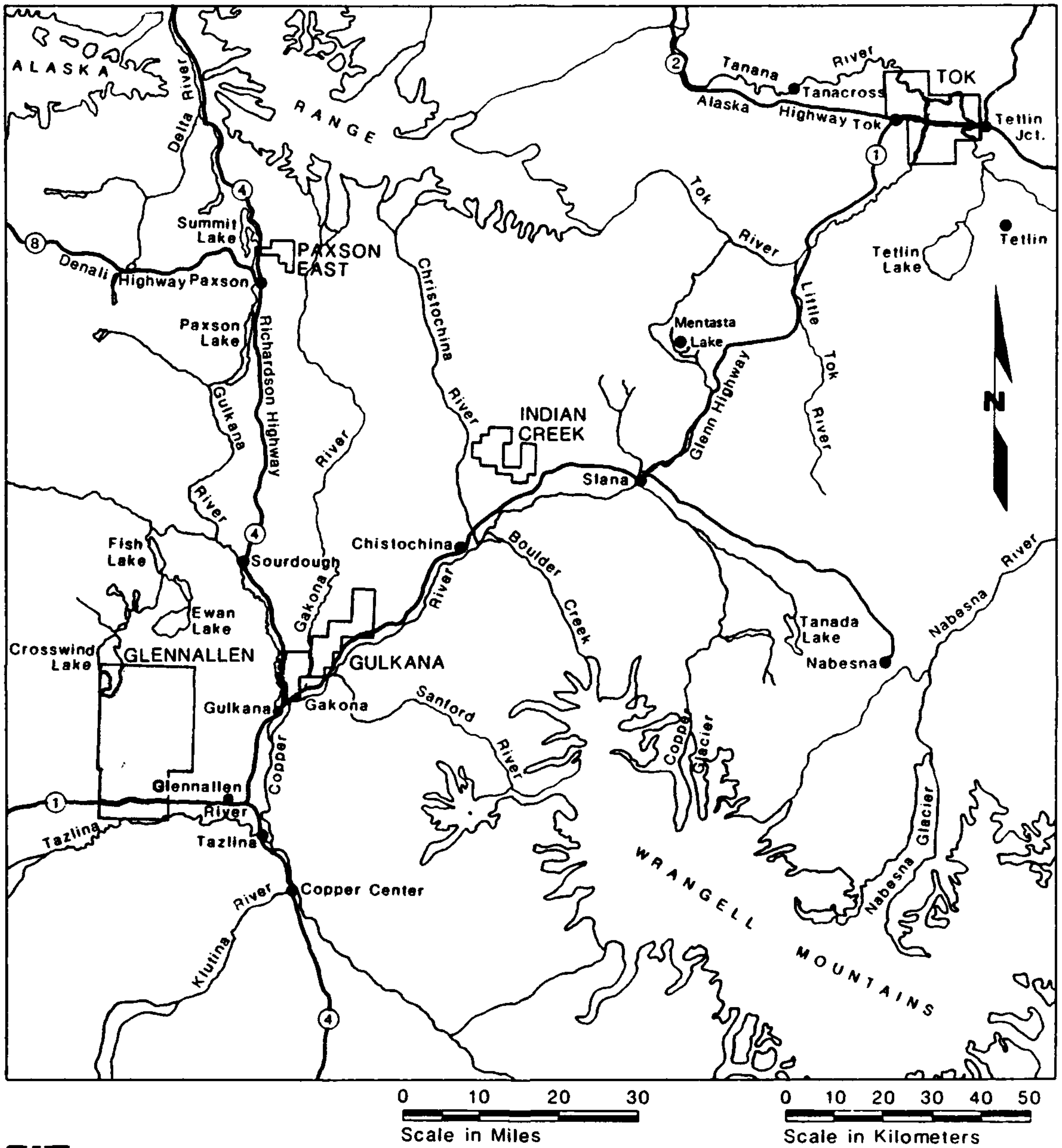
*Name of 1:250,000 USGS Alaska Series Map

+Name of 1:63,360 USGS Alaska Series Map



STUDY AREA LOCATION AND DESIGNATION

FIGURE 2-7 ALASKAN RADAR SYSTEM STUDY AREAS

because most features of the environmental setting do not conform to these precise descriptions, the analysis of impacts was not restricted to these arbitrary boundaries.

A site is the specific location within a study area where ARS facilities would be located. Specific sites have not yet been selected for the transmit and receive antenna arrays, pending the results of various environmental, operational, engineering, cost, and land availability studies that would influence the selection of a study area and the site within the study area.

2.1.2.2.1 Copper River Valley Region

This region consists of three study areas located in the large Copper River Basin. The region is bounded by the Alaska Range to the north, the Mentasta Mountains to the east, the Wrangell Mountains and Chugach Mountains to the south, and the Talkeetna Mountains to the west.

The Glennallen study area covers approximately 200 mi^2 about 12 miles northwest of the town of Glennallen. The area includes part of Crosswind Lake (in the northwest corner) and sections on both sides of the Glenn Highway as far south as the Tazlina River.

The Gulkana study area covers approximately 50 mi^2 beginning about 3 miles northeast of the junction of the Richardson Highway and the Tok Cutoff. The Copper River and Tulsona Creek flow along the southwest boundary of the study area, and the Gulkana River and Tulsona Creek flow along the western boundary. The Gakona River flows through the study area before meeting the Copper River near the southern border of the study area.

The Indian Creek study area covers about 20 mi^2 north of the Tok Cutoff where Indian Creek empties into the Copper River between the villages of Chistochina and Slana.

2.1.2.2.2 Alaska Range Region/Paxson East Study Area

The Alaska Range study region lies to the north of the Copper River Basin and has one study area.

The Paxson East study area covers 11 mi^2. It is on the east side of the Richardson Highway about 6 miles northeast of its junction with the Denali Highway. Summit Lake is across the road to the west, and Upper Fish Lake and Lower Fish Lake lie to the south. Fish Creek and the Trans-Alaska Pipeline pass through the study area.

2.1.2.2.3 Tanana Valley Region/Tok Study Area

The Tanana Valley study region lies in the Tanana River Valley, northeast of the Copper River Valley and separated from it by the Alaska Range and Mentasta Mountains. The region contains only one study area.

The Tok study area is composed of approximately 80 mi^2 between the towns of Tok and Tetlin Junction. The Alaska Highway traverses the study area before joining the Tok Cutoff at Tok. The Tok and Tanana Rivers cross the study area.

2.1.2.2.4 Elmendorf Air Force Base

Located on the northern outskirts of Anchorage, Elmendorf Air Force Base has been proposed as the operations center for the ARS.

2.1.2.3 Siting Alternatives

In selecting possible pairings of transmit and receive sites, not every study area can be matched with every other study area to form a site pair. For example, the transmit and receive sites must be separated by at least 50 nm. This eliminates several combinations such as Glennallen-Gulkana and Gulkana-Indian Creek. In addition, the Paxson East study area is adequate for constructing the transmit antenna arrays, but not the much longer receive antenna arrays. Table 2-2 shows the resulting combinations.

In choosing transmit and receive site locations, the Air Force would select one of the pairs listed in Table 2-2. Its choice would be based on operational, engineering, cost, and land availability considerations, as well as on environmental impacts.

Table 2-2

TRANSMIT-RECEIVE STUDY AREA PAIRINGS

	Transmit Areas		
	Glennallen	Paxson East	Tok
Receive Areas			
Glennallen	No	Yes	Yes
Gulkana	No	No	Yes
Indian Creek	Yes	No	Yes

2.1.2.4 Environmental Assessment

This EIS was prepared to aid decision making on the proposal to construct and operate the ARS, and includes an analysis of alternative areas to locate the transmit and receive sites. After the study areas for the transmit and receive sites have been selected, the Air Force

would analyze the specific sites within those areas for construction of the necessary roads, antenna arrays, buildings, and other facilities. Field studies in all areas to aid that design process have begun. Ultimately, most of the impacts would be influenced by specific siting of the facilities. Careful siting and mitigation measures probably can satisfactorily mitigate most impacts. Nevertheless, in addition to this EIS, the Air Force would prepare an environmental assessment of the selected sites before beginning construction. The environmental assessment would draw upon information gained from the field studies in progress, additional design details generated as system engineering continues, and the results of any post-EIS consultations with federal, state, and local officials.

2.2 Alternatives

2.2.1 No Action or Postponement of Action

In the no-action alternative, the ARS would not be constructed at any of the study areas. Until the decision was made to proceed, the alternative of postponing construction of the ARS would be equivalent to the no-action alternative.

No alternative means of radar surveillance and tracking will be available in the foreseeable future to substitute for the OTH-B radar. Therefore, because the threat from aircraft approaching North America remains significant, the U.S. would need to continue to compensate in its defensive military strategies for the lack of information that the OTH-B radar could provide.

2.2.2 Other Surveillance Systems

2.2.2.1 Aircraft Systems

The Air Force operates surveillance aircraft known as Airborne Warning and Control Systems (AWACS) that can track both aircraft and marine vessels. One possible alternative to the OTH-B system is a fleet of AWACS aircraft. However, each aircraft costs approximately $135 million. The cost to purchase, man, base, and operate the large number of aircraft required to match the proposed OTH-B coverage would be significantly more than the cost of the ARS.

2.2.2.2 Satellite Systems

The use of surveillance satellites is conceptually possible, but significant technical advances would be required to develop a wide-area surveillance system to detect aircraft and cruise missiles. New technology would be required for both satellite-borne surveillance equipment and computer systems to analyze and relay data received by the satellites. Consequently, satellite detection systems are not a feasible alternative to the OTH-B systems.

2.3 Comparison of the Environmental Consequences of the Alternatives

Section 3 describes each study area in detail. Section 4 sets forth the impacts of constructing and operating the ARS. This section focuses on the difference in impacts among the transmit study areas and among the receive study areas.

The alternatives to the proposed action (other than geographic alternatives) were described in Section 2.2. Neither airborne nor satellite surveillance systems are practical alternatives to the OTH-B system. Therefore, the impacts associated with these alternatives were not assessed and cannot be compared with the impacts from constructing and operating the ARS.

The alternatives of no action or postponement of action would avoid or defer the environmental impacts anticipated from construction and operation of the ARS. Deferral is usually considered when the possibility exists that some feature of the proposed action or the setting in which it would take place is likely to change in such a way that environmental impacts would be lessened. No such changes are expected in this situation. Consequently, taking no action would avoid the expected ARS impacts, and deferring action would postpone them, but no basis exists for expecting the impacts to become less significant.

2.3.1 Receive Study Areas

The Indian Creek study area, because of its more rugged terrain, may require more grading and borrow material. The access road to an Indian Creek site is of concern because of its potential length and proximity to Indian Creek. Glennallen would require less grading, but substantial amounts of borrow material would be needed in an area where gravel sources are scarce. Gulkana would be similar to Glennallen in these respects. Glennallen and Gulkana are also the most susceptible to permafrost damage.

Glennallen is the most sensitive biologically because of potential bird collisions, the bird flyway, the nesting of trumpeter swans, the presence of anadromous fish waters, and heavy subsistence and recreational uses. Gulkana is similar, but is less sensitive, because it is more remote from Crosswind Lake and from known trumpeter swan nesting areas. Indian Creek is sensitive with respect to anadromous fish waters and subsistence resources.

No significant socioeconomic difference exists between the Glennallen and Gulkana study areas because these areas lie on either side of the town of Glennallen. Socioeconomic impacts in either study area from ARS construction and operation could be positive. Significant impacts on the small communities around Indian Creek could occur because of the small number of inhabitants in the vicinity and the potentially large relative change the proposed project could bring. Employment opportunities would be significant. Effects on housing, electricity,

and schools, which are currently limited in this area, depend on how the project is implemented; the effects could be positive or negative.

The preceding discussion is summarized in Table 2-3.

2.3.2 Transmit Study Areas

2.3.2.1 Biophysical and Socioeconomic Effects

The terrain and long access road at Paxson East would require more grading and borrow material than the other sites, as well as precautions to protect Fish Creek. Tok and Glennallen would require less grading and borrow material. Gravel is plentiful in Tok, but scarce in Glennallen. The grading and borrow requirements at Glennallen are estimated to be significantly less as a transmit site than as a receive site because of the shorter length of the antenna array. Susceptibility to permafrost degradation is greatest in Glennallen and least in Tok, where the soils drain better.

Glennallen is the most sensitive biologically for the reasons mentioned in the receive site discussion. Tok lies in the Tanana River Valley, which is a major bird migration flyway, and is sensitive with respect to bird collisions, raptor nesting, and anadromous fish. Concern at Paxson East would focus primarily on disturbance of Fish Creek and the possible resulting impacts on anadromous fish waters.

The socioeconomic impacts on Glennallen would be identical to those summarized above. Impacts at Tok would be quite similar because of the similarity in the nature of these towns. Impacts at Paxson East would be similar to those for Indian Creek, discussed above. Again, the significance would depend on the way the project was executed.

The impact discussion is summarized in Table 2-4.

2.3.2.2 Electromagnetic Interference and Hazards

Available information indicates no factors that would allow discrimination among the study areas with respect to electromagnetic interference and hazard effects, except in one respect: the potential for such interference and hazards exists only near the transmit site.

Interference with amateur radio, air navigation, air or land mobile communication, or reception of broadcast television or international broadcast radio is unlikely. No hazard associated with fuel handling or the use of cardiac pacemakers would exist beyond the exclusion fence. The radar would not interfere with reception of broadcast radio in any area beyond about 1 to 2 miles from the transmit arrays.

Safe separation distances between the transmit arrays and electro-explosive devices would depend on the electrical conductivity of the ground. Available information is adequate to make preliminary estimates of these distances only, and is not adequate to differentiate among the transmit study areas.

Table 2-3

POTENTIAL IMPACTS
AT RECEIVE STUDY AREAS

Impact Factor*	Study Area: Glennallen	Gulkana	Indian Creek
Grading requirements	o	-	--
Borrow - requirements and availability	---	--	--
Surface wetness	--	--	-
Anadromous fish	-	--	--
Bird collisions	---	--	-
Large mammals	-	-	-
Subsistence	-	-	-
Disturbance of cultural resources	-	-	-
Aesthetics	-	-	--
Employment	++	++	+++

Key:
--- significant negative impact
-- negative impact
- possible negative impact
o no impact
++ positive impact
+++ significant positive impact

*Most factors depend on specific site locations within the study areas.

Table 2-4

POTENTIAL IMPACTS
AT TRANSMIT STUDY AREAS

Impact Factor*	Study Area: Glennallen	Paxson East	Tok
Grading requirements	o	--	-
Borrow - requirements and availability	--	--	o
Surface wetness	--	-	-
Anadromous fish	-	---	--
Bird collisions	---	-	---
Large mammals	--	-	o
Subsistence	-	-	-
Disturbance of cultural resources	-	-	-
Aesthetics	-	-	-
Employment	++	+++	++

Key:
--- significant negative impact
-- negative impact
- possible negative impact
o no impact
++ positive impact
+++ significant positive impact

*Most factors depend on specific site locations within the study areas

2.3.2.3 Radiofrequency Radiation Health Hazards

The RFR emitted by the ARS would be independent of the transmit study area selected. The distance of the exclusion fence from each transmit array would be chosen so that, for any specific site within any transmit study area, the maximum average power density beyond the exclusion fence would be below the American National Standards Institute (ANSI) 1982 standard for both occupational and general public exposure to RFR. Review of the relevant literature on biological effects indicated that no reliable scientific evidence exists to suggest that chronic exposure to the RFR levels below this standard would be deleterious to the health of even the most susceptible members of the population.

2.4 Long-Term Implications

If the proposed action is implemented, some adverse impacts that cannot be avoided would result from construction and operation of the ARS facilities. Land used for subsistence and for recreation would be removed; that land also would no longer be available as habitat for large mammals. Some birds may be lost from collision with the antenna arrays, but site selection and other mitigation measures could reduce such loss.

The proposed construction of the ARS would require materials and energy, as well as land. The commitments of energy would be irreversible and irretrievable. This would also be true for most materials. The land on which the major ARS structures are to be built may be irreversibly and irretrievably committed because of the expense of removing structures and other improvements, including gravel pads. The extent of earth moving and protection of the permafrost required to prepare a site will also determine the ability to return land to its current condition. However, the land used directly for such improvements would be only a part of the total land required. Most of the required land could be returned to current or similar uses, and the long-term productivity would be only partially diminished.

3 AFFECTED ENVIRONMENT

3.1 Introduction

This section describes the current environment of the study areas being considered for the ARS. This description forms the baseline from which potential impacts, described in Section 4, can be estimated and described. This section begins with the physical environment, then moves to the biological, socioeconomic, aesthetic, and cultural environments, and concludes with a discussion of the electromagnetic environment. The organization of Section 4 parallels that presented here so that the reader will be able to focus on topics of particular interest and note their impact in the subsequent section.

In this section, the environmental topics are discussed as the major headings, and discussion of the regional and specific study areas is subordinate to these topics. Where possible, characteristics applicable to several study areas are presented on a regional basis to avoid repetitious discussion for each study area.

The reader is referred to the glossary for assistance with technical or scientific terms that are used to describe the environment and the impacts. Common and species names for plants and animals are given in Appendix E.

3.2 Land and Minerals

3.2.1 Physiography and Topography

Three of the five study areas (Glennallen, Gulkana, and Indian Creek) lie within the Copper River Lowlands subdivision of the Pacific Mountain System, while the Paxson East study area lies within the Alaska Range subdivision (Figure 3-1). The Tok study area lies within the upper Tanana River Lowland subdivision of the Intermontane Plateaus.

3.2.1.1 Copper River Region

The Copper River lowlands consist of an intermountain basin flanked on all sides by mountainous uplands. The eastern part of the Copper River lowlands, which contains the Glennallen, Gulkana, and Indian Creek study areas, is a plain with elevations ranging from 1,000 to 3,000 ft. This plain is domirated by glacial moraines and bedrock ridges that rise above the relatively flat outwash surface. Most of the rivers that traverse the lowlands are fed by glaciers. Large lakes occupy deep basins in the mountain fronts, and thaw lakes are abundant on the eastern plain (Wahrhaftig, 1965).

Source: Waharhaftig, 1965

MAJOR PHYSIOGRAPHIC DIVISION BOUNDARY

PHYSIOGRAPHIC PROVINCE BOUNDARY

FIGURE 3-1 PHYSIOGRAPHIC PROVINCES OF ALASKA

3.2.1.1.1 Glennallen Study Area

The Glennallen study area (Figure 3-2) generally consists of a gently eastward-sloping, relatively flat plain dotted with numerous lakes of many sizes. Prominent features include Crosswind Lake in the northwest corner, Tolsona Creek along the west side, and the Glenn Highway traversing the southern portion. The highest elevation of approximately 2,200 ft occurs at the southwest corner, and the lowest elevation of approximately 1,650 ft occurs along the east side of the study area.

3.2.1.1.2 Gulkana Study Area

The Gulkana study area (Figure 3-3) consists generally of a gently southwest-sloping plain with numerous small lakes. Prominent features within the study area include the Gulkana River along the west side, the Gakona River through the center, Tulsona Creek in the eastern portion, and the Copper River along the southern edge. The highest elevation of approximately 2,000 ft occurs in the northeast corner, and the lowest elevation of approximately 1,600 ft occurs in the southwest corner.

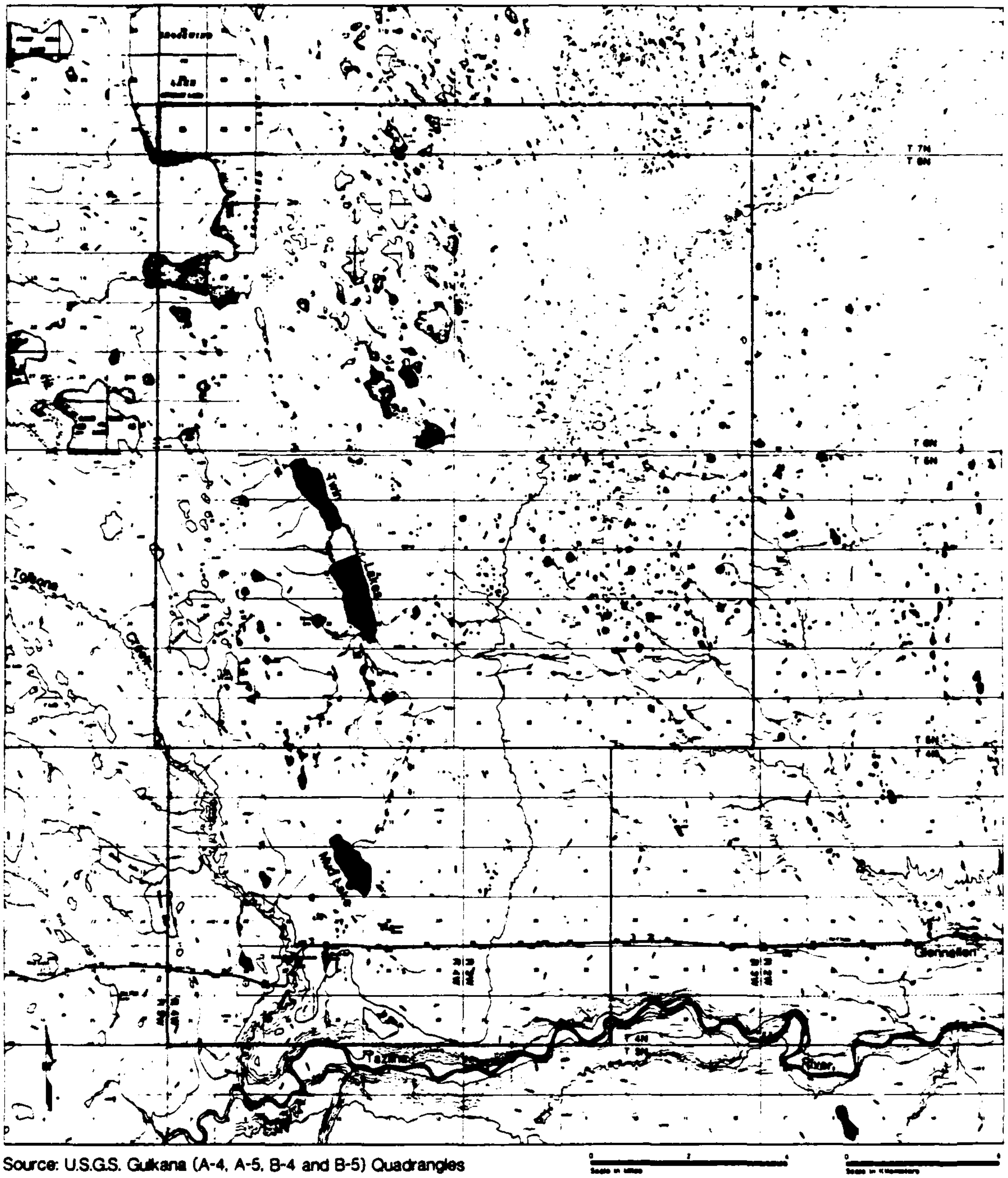
3.2.1.1.3 Indian Creek Study Area

The Indian Creek study area (Figure 3-4) has an irregular, double-pronged configuration whose northern edge is transitional between the Copper River lowlands and the foothills of the Alaska Range. The Chistochina River lies to the west of the study area, and the Copper River lies to the south. The lowlands in the southern portion of the study area contain numerous small lakes, and Indian Creek flows through the eastern portion of the area. The elevation of the study area ranges from 2,100 to 3,400 ft. The southern portion has relatively low relief, while the eastern and western prongs have relatively high relief.

3.2.1.2 Paxson East Study Area

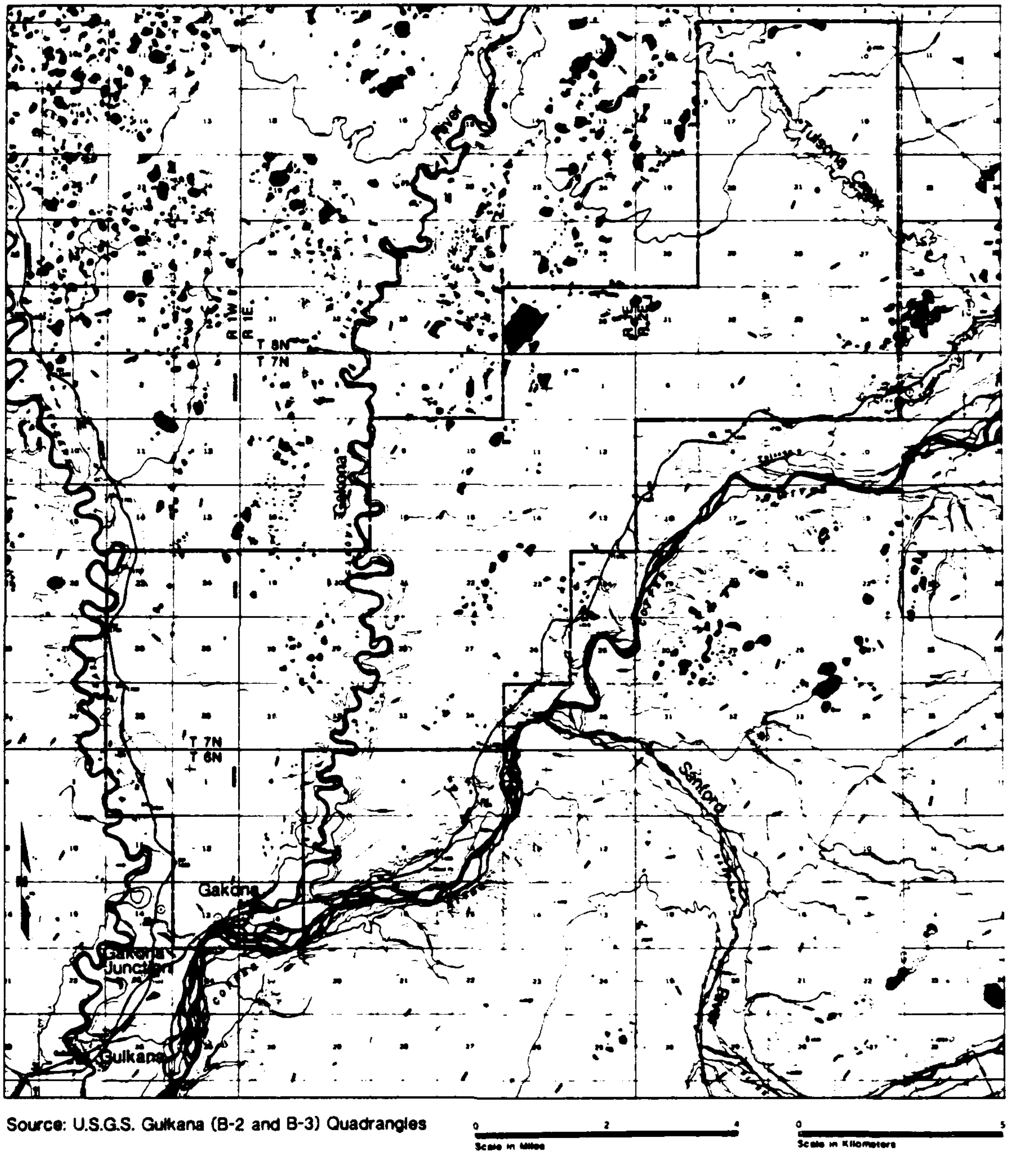
The Paxson East study area lies in the central and eastern part of the Alaska Range, which consists of two to three parallel, rugged, glaciated ridges at elevations of 6,000 to 9,500 ft. North-flowing tributaries of the Tanana River have cut deep canyons across the range, while swift-flowing, glacially fed streams along the southern flank of the range drain primarily into the Sustina and Copper Rivers. The high mountains are covered with snow and ice, generating valley glaciers up to 40 miles long. A few rock-basin lakes and many small ponds occur in areas of glacial moraine deposits.

Prominent features of the Paxson East study area include Fish Creek and Upper and Lower Fish Lakes, which lie at elevations between 3,250 and 3,400 ft within the southwestern and southeastern portions of the study area (Figure 3-5). The steepest grades (14%) occur along the



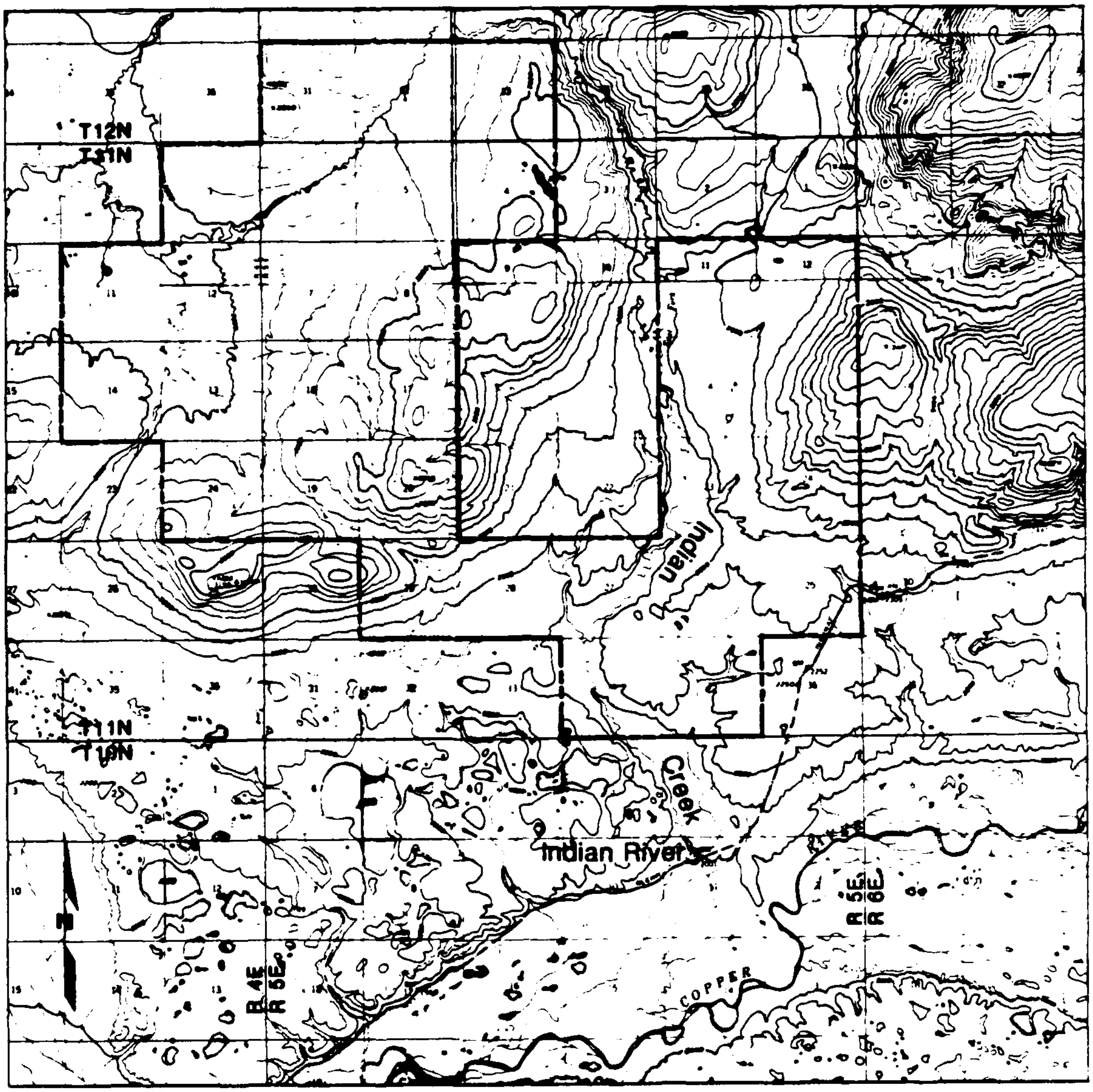
Source: U.S.G.S. Gulkana (A-4, A-5, B-4 and B-5) Quadrangles

FIGURE 3-2 TOPOGRAPHY, GLENNALLEN STUDY AREA



Source: U.S.G.S. Gulkana (B-2 and B-3) Quadrangles

FIGURE 3-3 TOPOGRAPHY, GULKANA STUDY AREA

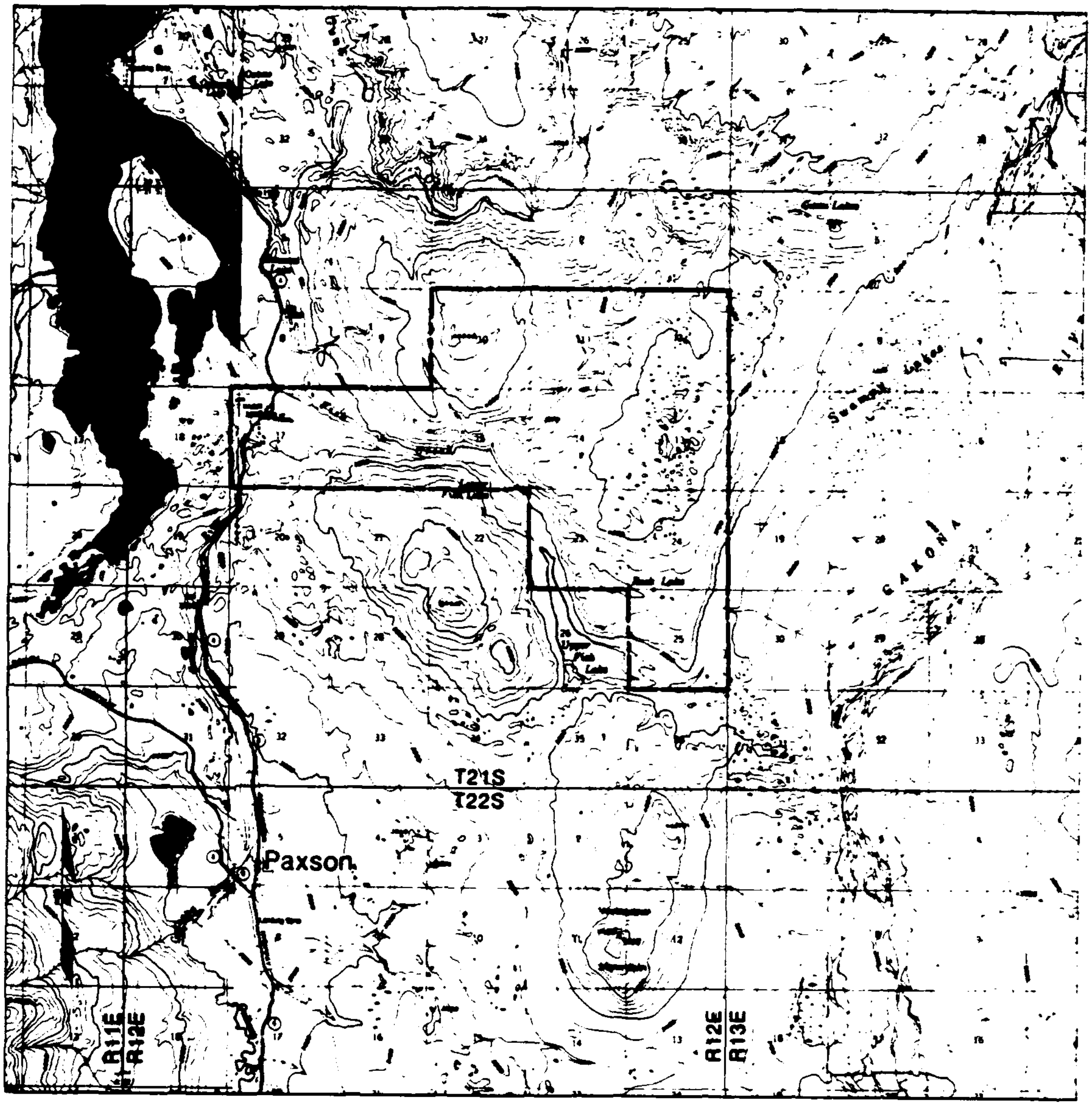


Source: U.S.G.S. Gulkana (C-1, C-2, D-1, and D-2) Quadrangles

0 2 4 Scale in Miles

0 5 Scale in Kilometers

FIGURE 3-4 TOPOGRAPHY, INDIAN CREEK STUDY AREA



Source: U.S.G.S. Mt. Hayes (A-3 and A-4) Quadrangles

0 2 4 Scale in Miles

0 5 Scale in Kilometers

FIGURE 3-5 TOPOGRAPHY, PAXSON EAST STUDY AREA

banks of Fish Creek. The northern portion of the study area includes a broad, flat peak reaching about 4,340 ft; another broad, elongated, north-northeast trending peak occupies approximately 3 mi^2 in the western portion of the study area.

3.2.1.3 <u>Tok Study Area</u>

The upper Tanana River lowlands form a broad depression along the Tanana River east of Fairbanks and north of the Alaska Range. Outwash fans from the Alaska Range slope northward to flood plains along the axis of the lowlands. Numerous rivers from the range flow north from the heads of the fans in broad, terraced valleys; their deposits have pushed the Tanana River against the base of the hills on the north side. Thaw lakes are common in areas underlain by fine alluvium, and thaw sinks are abundant in areas of thick loess cover (Wahrhaftig, 1965).

The Tok study area is situated around the confluence of the Tanana and Tok rivers (Figure 3-6). The Tanana River traverses almost 15 miles of the study area, while the Tok River traverses about 17 miles. Two small streams cross the study area in the west and south.

The study area is relatively flat, ranging from a low of 1,600 ft in the northwest corner to 1,680 ft in the center. Northeast of the Tanana River are a few broad hills with elevations up to approximately 2,300 ft. Portions of the study area are low-lying and swampy with large tracts of muskeg; other areas contain gravel and are well drained.

3.2.2 <u>Land Status</u>

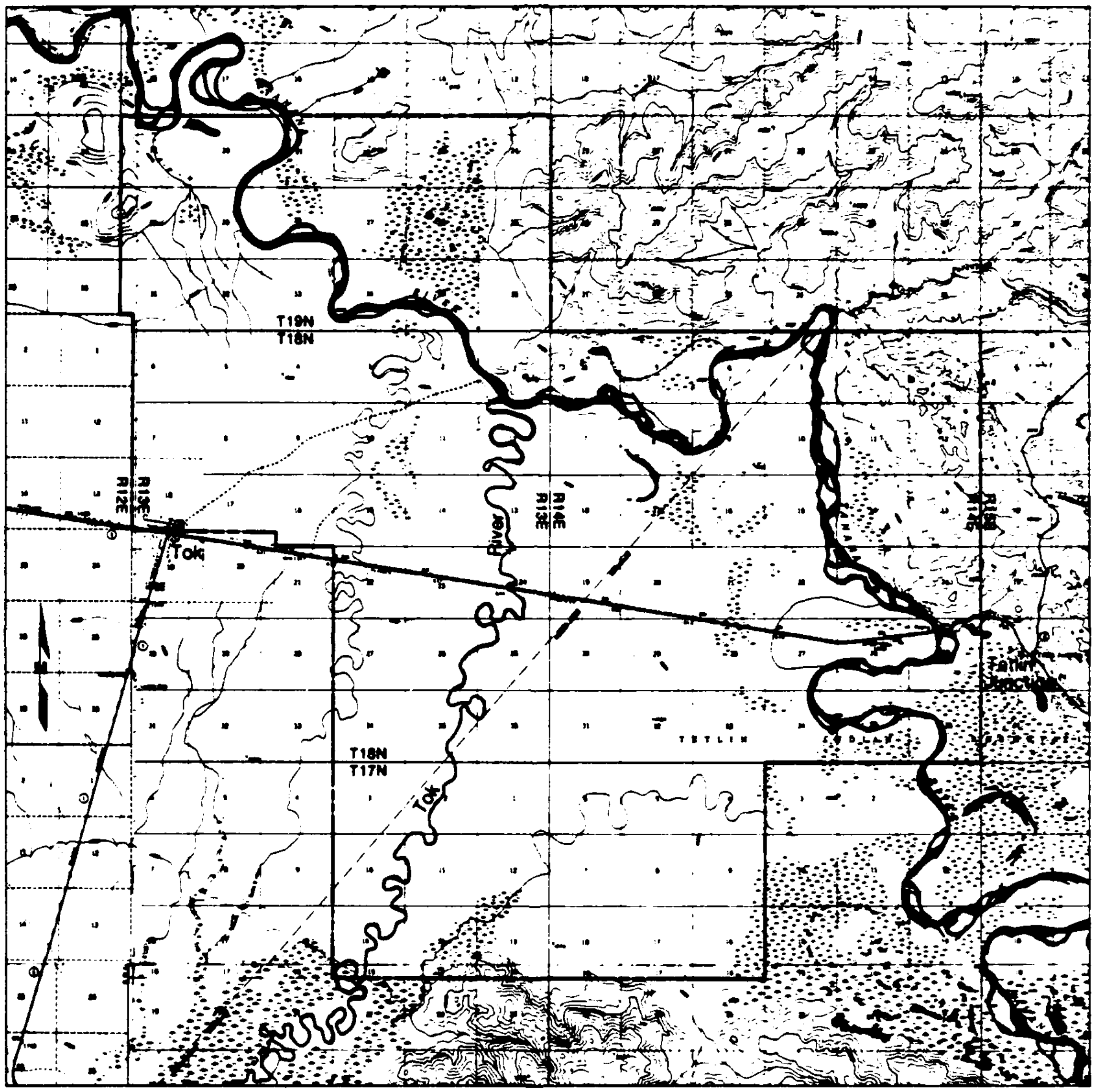
Land status for the five study areas has been determined and mapped using the following sources of information:

- U.S. Department of Interior, Bureau of Land Management (BLM)--Land Status Plats and Detail Supplements

- State of Alaska, Department of Natural Resources, Division of Lands (ADL)--Land Status Plats and File Updates

- State of Alaska, Division of Geological and Geophysical Surveys (DGGS), Resource Mapping Program--General Land Ownership Maps.

Land status categories referenced in this document are consistent with those presented in the General Land Ownership Maps of the Alaska Resource Mapping Program; land status has been updated using more recent BLM and ADL land plats. The individual ownership of private lands has not been mapped. Land status is summarized in Figures 3-7 to 3-11. The legend for these figures is shown as part of Figure 3-7.



Source: U.S.G.S. Tanacross (A-4, A-5, B-4, and B-5) Quadrangles

FIGURE 3-6 TOPOGRAPHY, TOK STUDY AREA

3.2.2.1 Glennallen Study Area

As shown in Figure 3-7, the western part of the Glennallen study area contains both State of Alaska approved and tentative federally-approved land selections. The BLM and ADL land status plats show a series of privately held 5- to 65-acre oil and gas, coal, and mineral right-of-way leases bordering the shoreline of Crosswind (Charley) Lake. Private, Native-allotment, and state-acquired land parcels ranging from approximately 1 to 160 acres lie adjacent to the Glenn Highway right-of-way and the Tolsona Lake shoreline.

The eastern portion of the study area contains federal lands with Native and village corporation selections. An 80-acre Native-allotment land parcel is located in this portion of the study area, and the Ewan Lake Trail runs north-south through it. No patented or unpatented mining claims or oil and gas leases exist in the eastern portion of the study area.

3.2.2.2 Gulkana Study Area

As shown in Figure 3-8, the majority of the Gulkana study area consists of federal lands that have been conveyed to Ahtna, Inc., the Native corporation in this area. Also shown are a number of areas with multiple selections by the State of Alaska, Ahtna, Inc., and two of Ahtna's village corporations, which are still awaiting final conveyance. Near Gakona are a number of privately owned and university-selected land parcels, as well as powerline right-of-way easements adjacent to the Glenn Highway. A number of oil and gas right-of-way leases lie adjacent to the Glenn and Richardson Highways and the Copper, Gakona, and Gulkana Rivers. No patented or unpatented mining claims are located in the study area.

3.2.2.3 Indian Creek Study Area

As shown in Figure 3-9, most of the Indian Creek study area lies within federal land that has been conveyed to Ahtna, Inc. The northwestern portion of the study area includes land with state-approved selections. An undivided Native allotment of approximately 80 acres is located in the southeastern portion of the study area. No mining claims or oil and gas leases are located within the study area.

3.2.2.4 Paxson East Study Area

As shown in Figure 3-10, the majority of the Paxson East study area consists of federal land selected by the State of Alaska. The remaining areas are classified as part of state federal-grant lands with tentatively approved selection. No privately owned mining claims or oil and gas leases exist within the study area. The 100-ft Trans-Alaska Pipeline System right-of-way lease runs north-south through the study area.

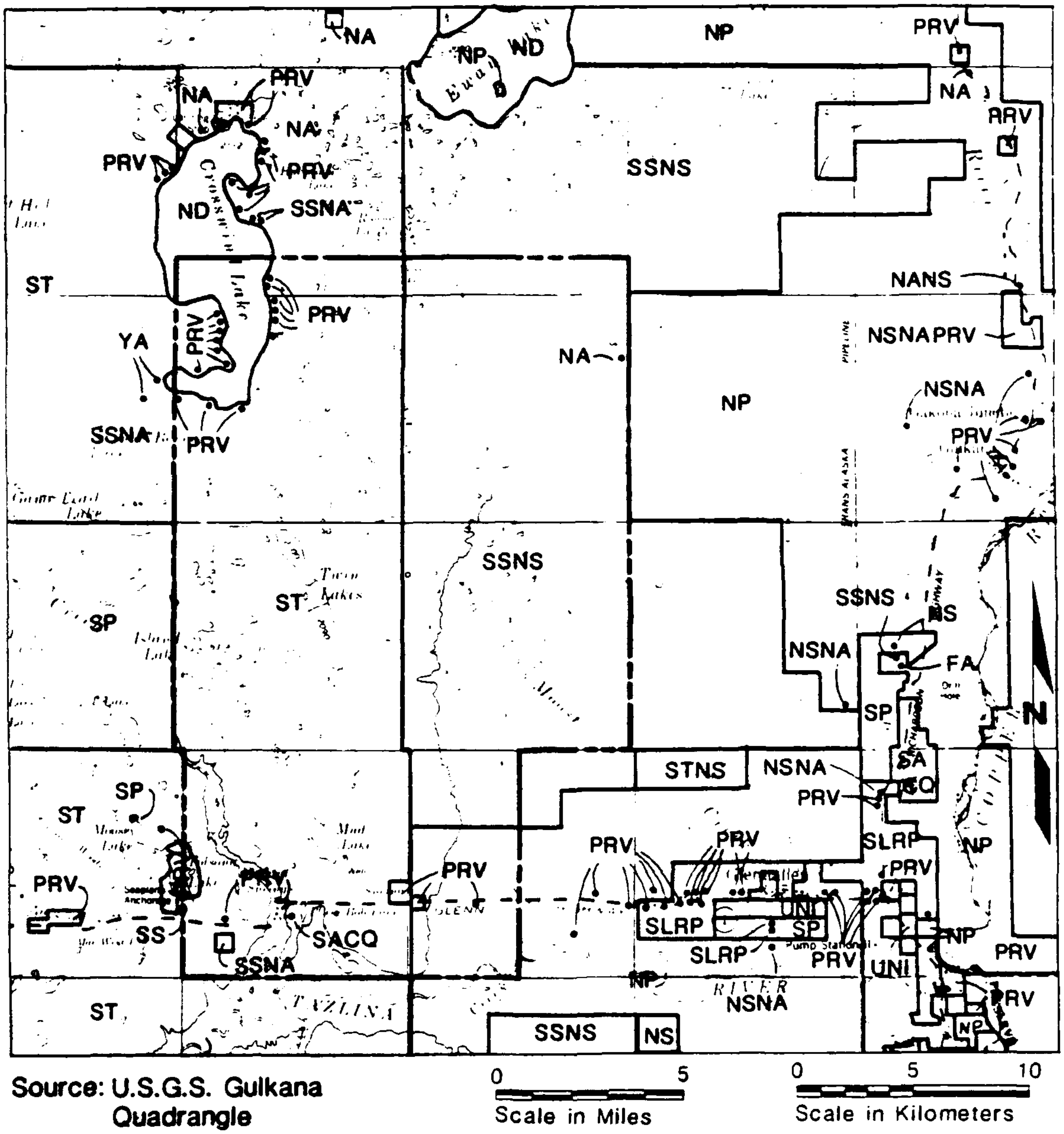


FIGURE 3-7 LAND STATUS, GLENNALLEN STUDY AREA

LEGEND FOR FIGURES 3-7 TO 3-11

Federal Land

F	Bureau of Land Management land
FA	Withdrawn Federal land for an active federal system or use
HE	Federal land with trade and manufacturing site, headquarters site or homestead application
NA	Federal land with Native allotment application
ND	No data
NP	Federal land conveyed to a Native Corporation
NS	Federal land with pending Native Corporation selection
PRV	Federal land conveyed into private ownership
SS	Federal land with pending State of Alaska selection

State Land

MP	*State of Alaska* land conveyed to a municipality
MS	State of Alaska land selected for ownership by a municipality
SACQ	Land acquired by a State agency for State use
SC	State of Alaska land sold or conveyed to others
SCH	State of Alaska school grant land retained by the state
SCHC	State of Alaska school grant land sold or conveyed to others
SLRP	State of Alaska land offered for disposal via a remote staking program
SP	Land patented to the State of Alaska
ST	State of Alaska approved land selection from the Federal government
UNI	University of Alaska land

Land Parcels with Multiple Ownership Claims Are Identified with Combinations of the Codes, for Example

SSNSNA	Federal land with Native allotment application and pending Native Corporation and State of Alaska selections

Source: State of Alaska DNR, compiled by Dale Tubbs & Associates, 1984.

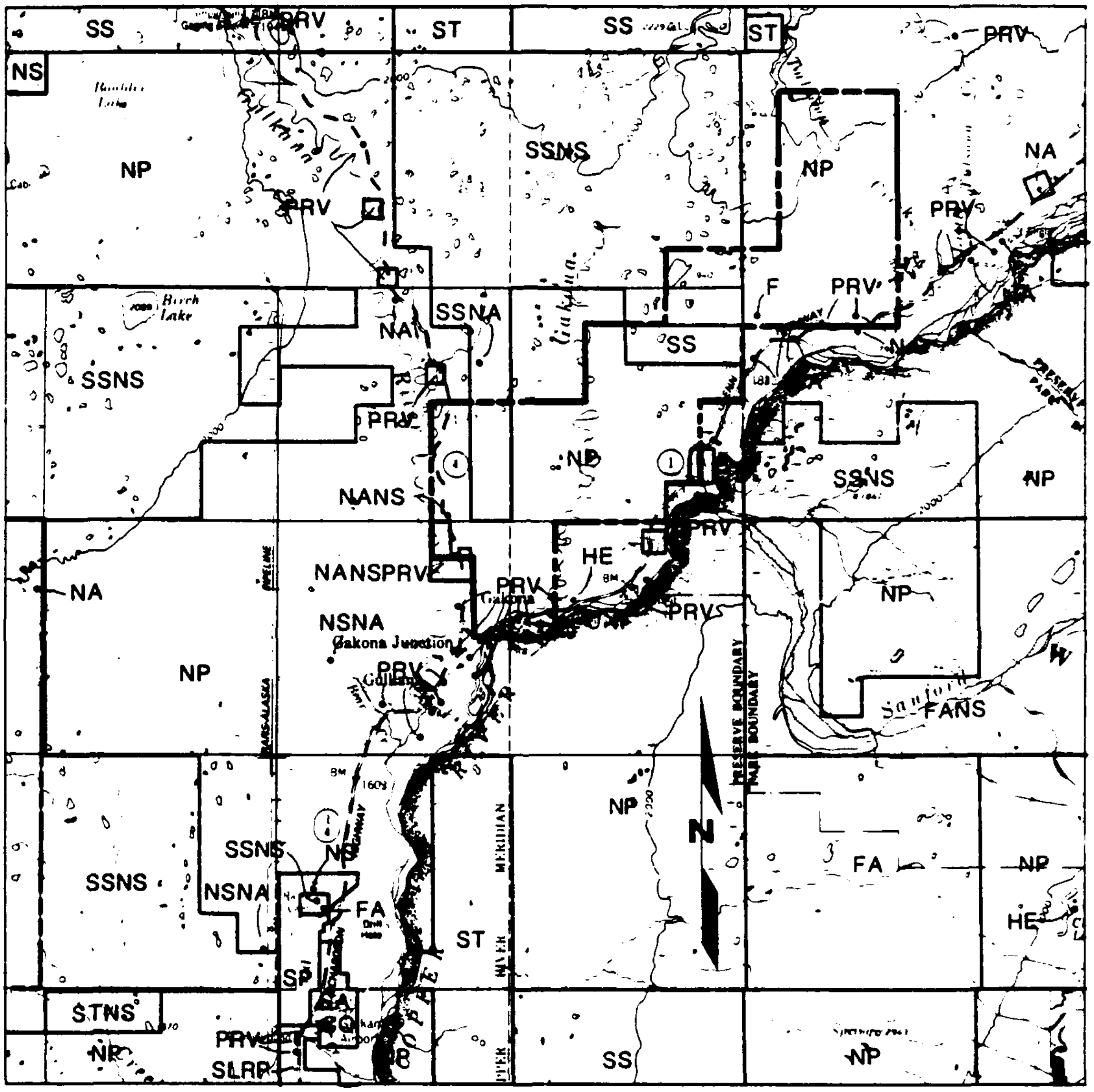
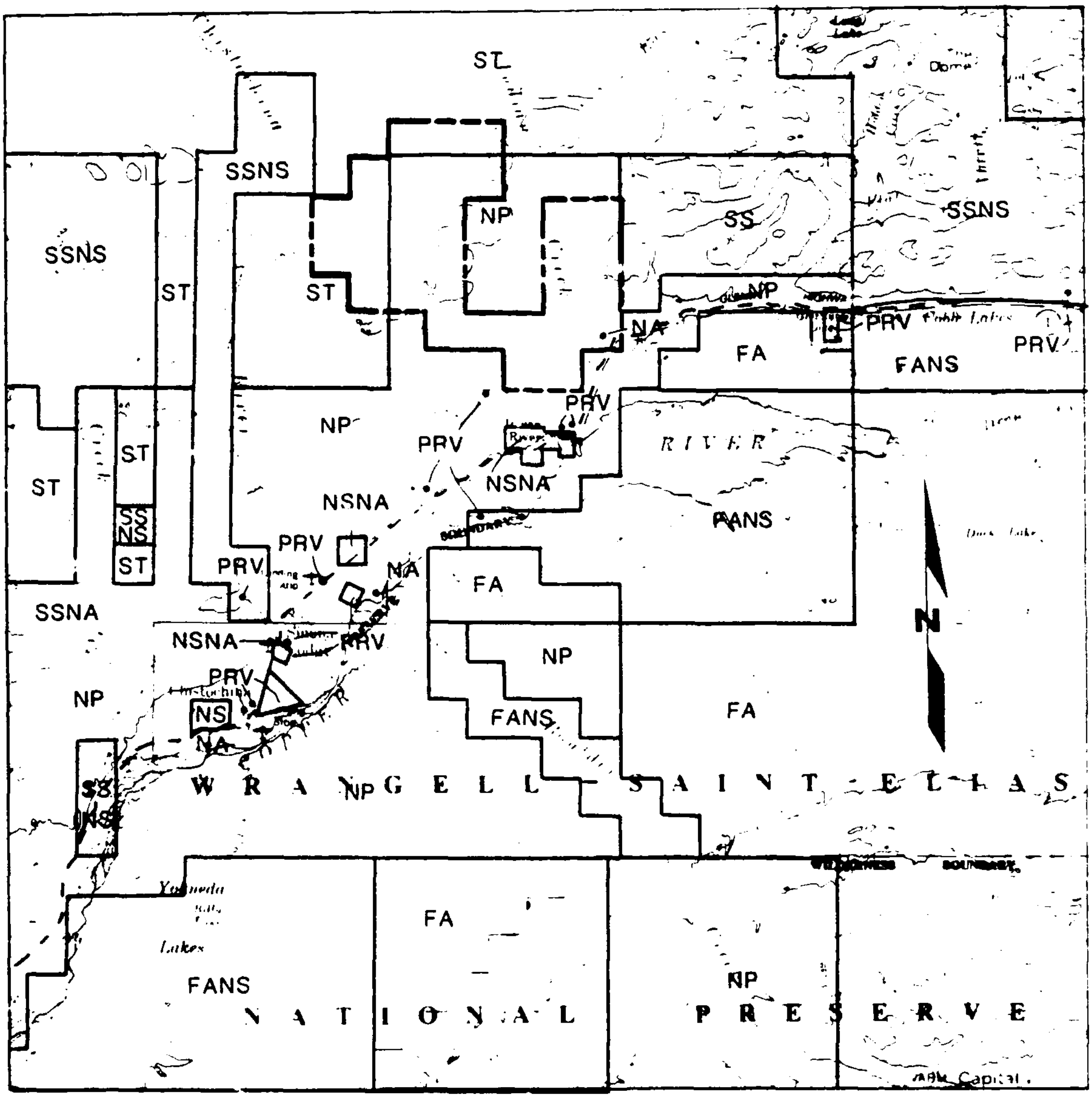


FIGURE 3-8 LAND STATUS, GULKANA STUDY AREA

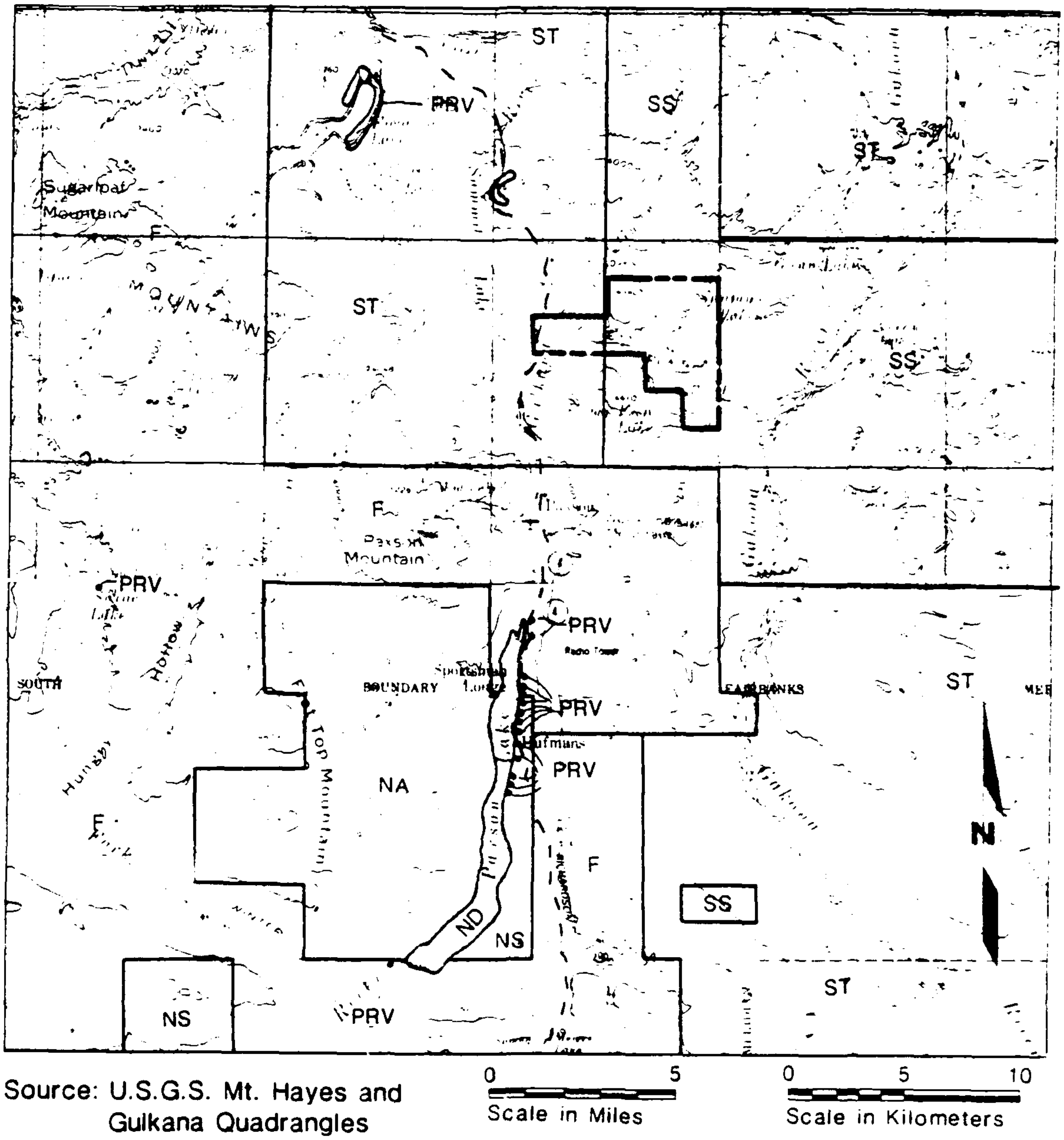


Source: U.S.G.S. Gulkana Quadrangle

0 5 Scale in Miles

0 5 10 Scale in Kilometers

FIGURE 3-9 LAND STATUS, INDIAN CREEK STUDY AREA



Source: U.S.G.S. Mt. Hayes and
Gulkana Quadrangles

FIGURE 3-10 LAND STATUS, PAXSON EAST STUDY AREA

3.2.2.5 Tok Study Area

As shown in Figure 3-11, much of the Tok study area lies within the boundaries of the former Tetlin Indian Reservation, now selected by the Tetlin Native Corporation. Adjacent to the eastern border of the former reservation is a triangular piece of land that is classified as dual ownership. This disputed land is part of state federal-grant lands with both tentatively approved selection by the state and claims by the Tetlin Native Corporation; ADL land status plats indicate that the ownership of this land is being appealed and is under review. The northwestern portion of the study area includes state-approved land. Some privately owned parcels occur in Native-selected lands near the village of Tok. The remaining portion of the Tok study area lies within state federal-grant lands with tentatively approved selection by the state. Two small parcels (less than 160 acres each) of village-selected land are located in the northwestern portion of the study area adjacent to the south bank of the Tanana River.

Near the Alaska Highway right-of-way corridor are a number of roughly parallel dedicated right-of-way easements: the Haines-Fairbanks POL Pipeline, the proposed Alaska Natural Gas Transportation System (ANGTS) pipeline, and the Alaska Railroad (ARR). No private lands, mining claims, or oil and gas leases are located within the Tok study area.

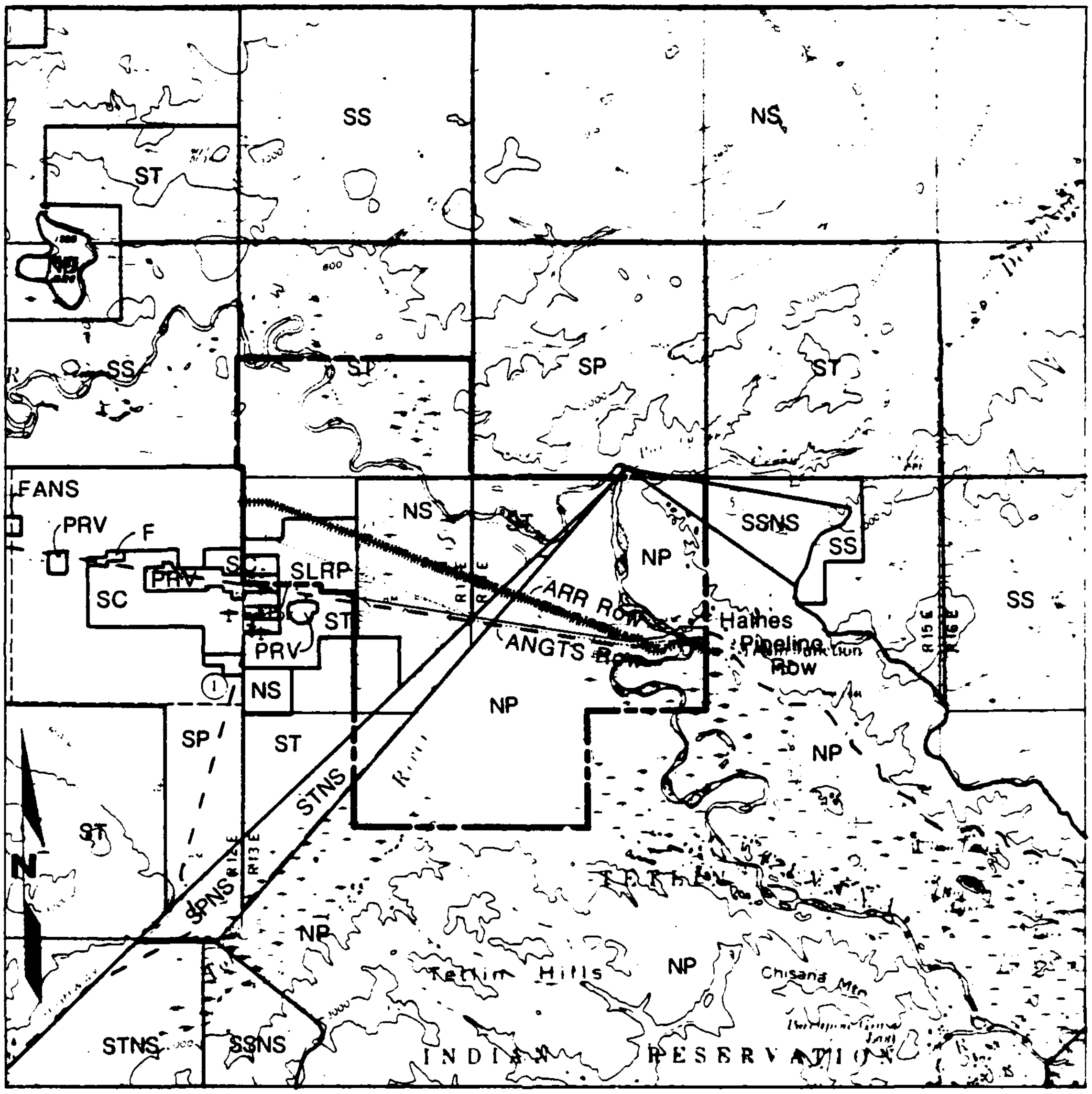
3.2.3 Geology and Soils

Information on the geology and soils of the Copper River Lowlands, Alaska Range, and upper Tanana River lowlands is presented below. These sections address the bedrock, surficial sedimentary deposits, soils, and permafrost.

3.2.3.1 Copper River Region

Sandstone and shale of Mesozoic age underlie the southern and eastern portions of the Copper River lowlands; metamorphosed volcanic and sedimentary rocks of Paleozoic age underlie the northern portions; and older basement rocks underlie the eastern portion (Figure 3-12). Bedrock outcrops are generally confined to isolated knobs on the Lake Louise Plateau in the eastern part of the lowlands.

Surficial deposits consist of thick accumulations of predominantly Quaternary-age sediments, including morainal, stagnant-ice, and lacustrine deposits up to 500 ft thick (Wahrhaftig, 1965). During the last glaciation (10,000 to 100,000 years ago), ice blocked all the major drainage channels, forming an extremely large lake within the lowlands (Figure 3-12). Multiple episodes of lake development and deposition left sequences of thin sand and gravel deposits overlain by thicker, finely laminated silt, clay, and fine sand. Glacial meltwaters resulted in the deposition of fine-grained soil particles, primarily along the main drainage channels.

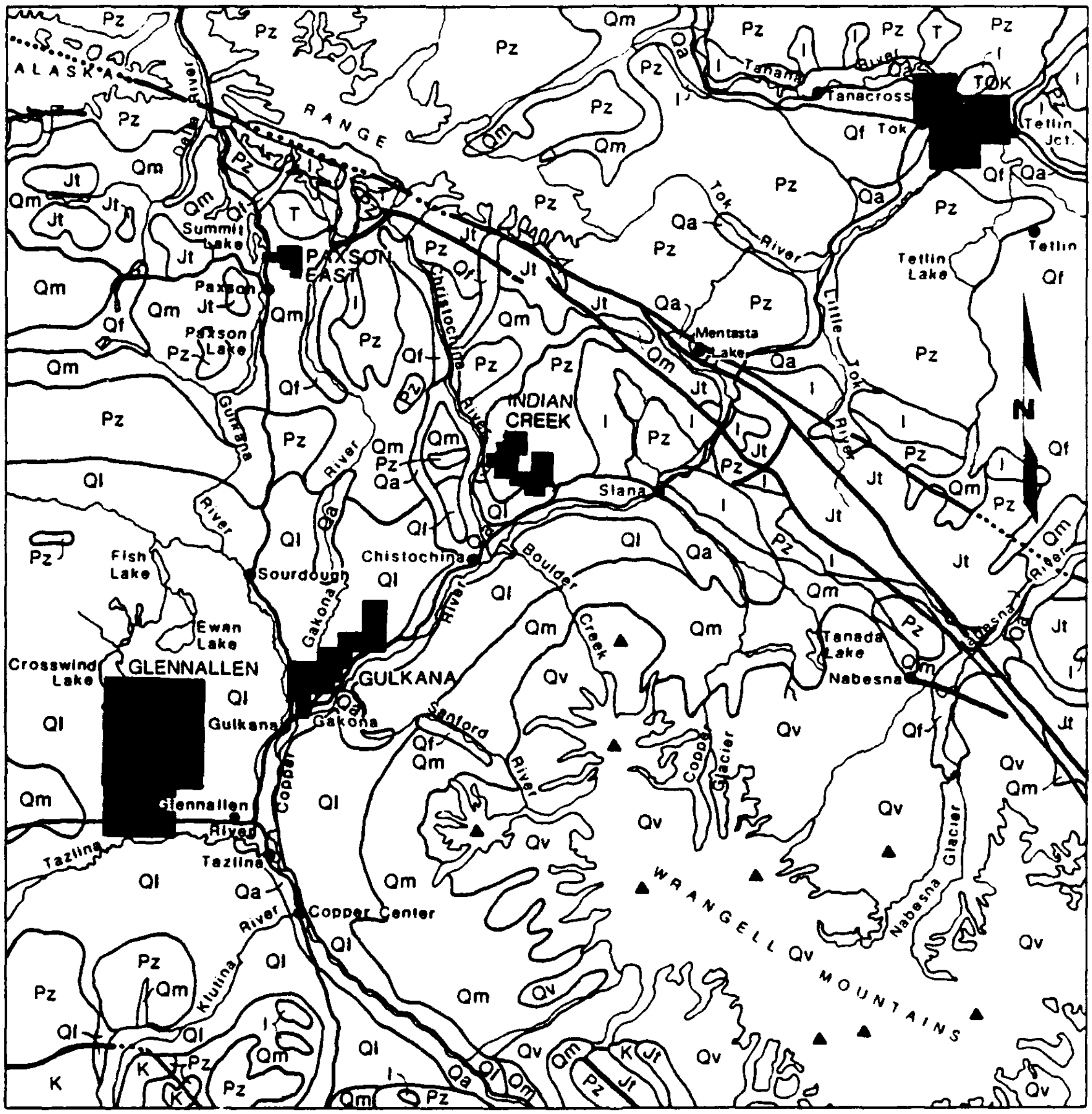


Source: U.S.G.S. Tanacross Quadrangle

0 5 Scale in Miles

0 5 10 Scale in Kilometers

FIGURE 3-11 LAND STATUS, TOK STUDY AREA



Source: Moffit, 1938, 1954 and Foster, 1970

0 10 20 30 Scale in Miles

0 10 20 30 40 50 Scale in Kilometers

- Qa Alluvial terrace and flood plain deposits
- Qf Glaciofluvial outwash deposits
- Qm Pleistocene glacial till and moraine deposits
- Ql Glaciolacustrine-Silt-rich, proglacial lake deposits
- Qv Volcanic rocks of the Wrangell Mtns.
- T Sandstone, Shale and Conglomerate w/coal seams
- K Metamorphosed sedimentary and volcanic rocks
- Jt Sandstone and shale with interbedded volcanics
- Pz Metamorphic schists, gneiss and crystalline limestone
- I Intrusive igneous rocks
- Contact between geologic units
- Fault, dashed where inferred
- ▲ Recent or active volcano

FIGURE 3-12 REGIONAL GEOLOGY

The relatively young geologic age of parent materials in the Copper River lowlands results in poorly developed soil profiles. Soils are generally classified as poorly drained, clayey to loamy soils with a peat surface layer and shallow permafrost table. Isolated areas of well-drained, gravelly loam with deep permafrost also are present (Selkregg, 1974). The erosion potential of these soils is generally moderate.

The Copper River lowlands lie within the zone of discontinuous permafrost. Because of extensive fine-grained deposits in former lake beds, moderately thick to thin ice-rich permafrost may exist in this region (Figure 3-13). Where present, this permafrost may extend from near the ground surface to depths of approximately 600 ft (Ferrians, 1965). Areas of coarse-grained deposits are generally underlain by discontinuous or isolated masses of permafrost. Locally, permafrost is absent around large bodies of water. The temperature of the permafrost typically ranges from -5° to 1° C.

3.2.3.1.1 Glennallen Study Area

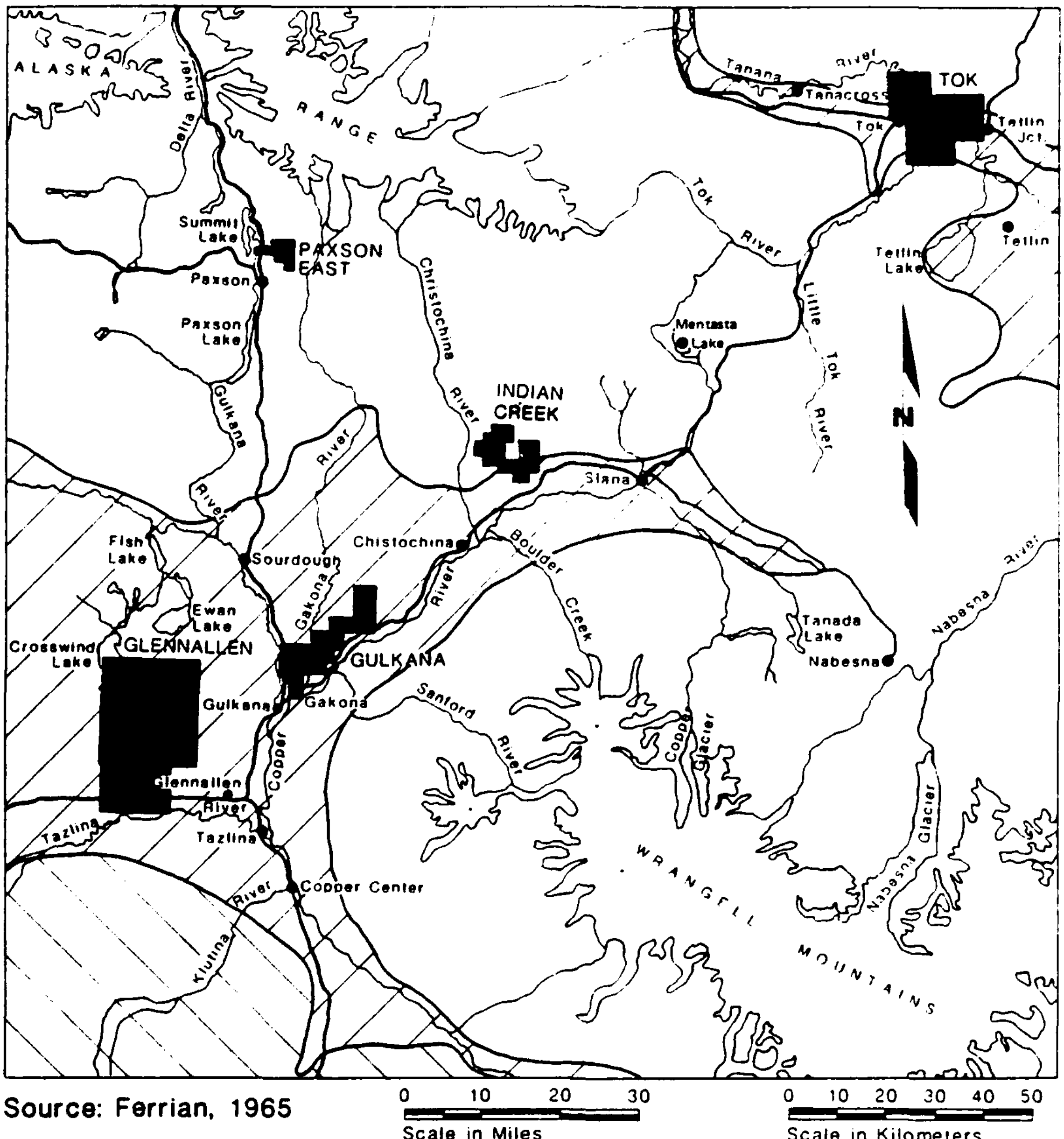
The geology of the Glennallen study area is dominated by Quaternary lacustrine deposits consisting of silt and fine sand interspersed with lesser amounts of sand, clay, and scattered gravel. A U.S. Geological Survey boring approximately 8 miles east of the study area (Yehle, Odum, and Reneau, 1985) indicates that a 90-ft section of near-surface lacustrine deposits overlies older alluvial sand and gravel. Isolated areas of peat occur along the west side of the study area, and recent alluvial sand and gravel occur in the Tolsona Creek and Tazlina River drainages.

Soils typically consist of poorly drained loams and clayey loams with a thin, peaty surface layer. The fine-grained lacustrine deposits are highly susceptible to frost. and moderately thick to thin permafrost may exist throughout the study area.

3.2.3.1.2 Gulkana Study Area

The geology of the Gulkana study area is also dominated by Quaternary lacustrine deposits. Drilling logs from along the Richardson Highway north of the study area indicate that the thickness of near-surface deposits exceeds 125 ft. Alluvial sand and gravel deposits associated with the Gulkana, Gakona, and Copper Rivers occur along the western, central, and southern portions of the study area. Scattered surface accumulations of peat occur in the northeast, and fine sand and silt eolian deposits exist near Gakona along the Gakona River.

Soils are typically poorly drained, clayey loams with a peaty surface layer and shallow permafrost table (Selkregg, 1974). The fine-grained soils are susceptible to frost , and moderately thick to thin permafrost may exist throughout the study area.



Source: Ferrian, 1965

Moderately thick to thin permafrost in fine-grained deposits and discontinuous or isolated masses of permafrost in coarse-grained deposits

Isolated masses of permafrost

Discontinuous permafrost

FIGURE 3-13 REGIONAL PERMAFROST DISTRIBUTION

3.2.3.1.3 Indian Creek Study Area

The Indian Creek study area exhibits more variable geology. Upland areas on the east side of both prongs of the study area consist predominantly of bedrock outcrops with metamorphosed sedimentary, volcanic, and granitic rocks of Paleozoic age. The southern lowlands consist primarily of lacustrine silt with scattered sand and gravel of Quaternary age. The central portion of the study area is dominated by alluvial and glacial-fluvial terrace deposits along the Indian Creek drainage.

The study area contains primarily thin, well-drained soils in the upland area and poorly drained soils with peaty surface layers in the lowland areas. Discontinuous permafrost could occur throughout the northern part of the study area, while moderately thick to thin permafrost could occur in the southern part.

3.2.3.2 Paxson East Study Area

The Paxson East study area is on the southern flanks of the Alaska Range. The bedrock geology of the Alaska Range depicts a complicated history of recurring folding, faulting, and igneous intrusion. Generally, the older Precambrian and Paleozoic rocks consist of schist, gneiss, and crystalline limestone, while the Mesozoic rocks consist largely of deformed sedimentary rocks of marine origin. Large bodies of intrusive igneous rocks were introduced during late Mesozoic and early Tertiary times.

On the south flank of the Alaska Range, ice-cap conditions prevailed over large areas, resulting in extensive upland morainal deposits of unsorted sand, gravel, silt, and till, along with valley deposits of outwash sand and gravel (Pewe, 1975). Soils in the Alaska Range are typically confined to the foothill areas and depressions within higher-altitude valleys. These soils are generally thin, well-drained, highly acidic, gravelly loams with a deep permafrost table (Selkregg, 1974). Deposits of loess are found along the Delta River valley.

Upland portions of the Paxson East study area consist primarily of Paleozoic bedrock areas covered by a thin mantle of glacial deposits; lowland portions contain thicker deposits of glacial, fluvial, and alluvial materials. Bedrock includes metamorphosed, fault-bounded sedimentary and volcanic rocks that have been intruded into by younger, granite rocks. Glacial deposits of two ages cover the study area; the older (deeper) deposits consist of moderately well-sorted gravel and sand, while the younger (shallower) contain poorly sorted boulders, gravel, and sand.

Recent deposits along the Fish Creek drainage consist of alluvial fan and fluvial materials, which contain poorly sorted boulders, gravel, sand, and silt. Soils in the southern and southwestern upland portions of the study area consist primarily of well-drained, thin, strongly acid

soils with deep permafrost, while soils in the lowlands consist primarily of poorly drained deposits with peaty surface layers and shallow permafrost. The northern and northeastern portions of the study area contain well-drained, thin soils or rock-strewn slopes with deep permafrost. The large north-northeast-trending hill in the northeastern portion of the study area is a lateral moraine formed by the Gakona Glacier.

3.2.3.3 Tok Study Area

The Tok study area lies within the upper Tanana River lowlands, an east-west-trending valley flanked on the north and south by bedrock uplands. Bedrock outcrops in the lowlands are typically limited to scattered knobs and hills that protrude through the alluvial and outwash fan deposits.

The upper Tanana River lowlands are dominated by fluvial and glaciofluvial deposits. The central and northern portions of the lowlands consist primarily of low terrace and floodplain deposits composed of silt and sand with scattered peat, while the southern portion of the lowlands west of the Tetlin Lake area is dominated by talus slopes and outwash and alluvial fans that originate in the Alaska Range. East of Tetlin Lake, the south side of the lowlands is primarily fluvial and lacustrine sand and silt with minor peat. Scattered dunes of wind-deposited silt and sand also occur in the general vicinity.

The upper Tanana River lowlands are typically covered by loamy soils (Selkregg, 1974). Wet loams with thick surface organic mats generally occupy the low areas along the river, while poorly drained loams occur on the sandy, gravelly terrace deposits along the foothills and outwash plains. Deposits of loess can be significant at the lower ends of tributary valleys, but generally become thinner with increasing elevation and distance from the river. The soils are considered to have moderate erosion potential.

The upper Tanana River lowlands lie within the zone of discontinuous permafrost. Because of the extensive, relatively coarse-grained outwash and alluvial fan deposits, most of the area is probably underlain by discontinuous or isolated masses of permafrost (Selkregg, 1976). Scattered, fine-grained deposits may contain moderately thick to thin permafrost.

The geology of the Tok study area consists of old Paleozoic and Mesozoic metamorphic and intrusive rocks along with young glacial, fluvial, and alluvial deposits. The older rocks, underlying the entire area and outcropping only in the southernmost portion of the study area, consist of highly metamorphosed sedimentary rocks. Intrusive granitic rocks are exposed at the surface in three areas; the east abutment of the Tanana River bridge was constructed in this granite.

The oldest Quaternary sediments, consisting of outwash sand and silt deposits of the Delta Glaciation, occur along the Alaska Highway in the center of the study area. Younger deposits from the Donnelly Glaciation form these predominantly gravel outwash aprons and alluvial fans over the western and southern portions of the study area. Fluvial and lacustrine deposits of ice-rich sand, silt, and organics occur primarily in the eastern portion of the study area, east of the Tanana River. The most recent deposits consist primarily of silt and sand along the Tanana River and gravel and sand along the Tok River.

Soils east of the Tok River range from well-drained brown soil to poorly drained peaty soil; the latter may contain shallow permafrost. Soils west of the Tok River are generally well drained with less prevalent permafrost.

3.2.4 Geohazards

Temperature-induced ground movements (frost heave and subsidence), flooding, volcanically related activities, and seismicity are the main geological hazards affecting human developments in southcentral Alaska.

Thaw settlement, caused by increasing heat input or by decreasing the amount of insulation, can occur in areas underlain by frozen ground. Areas most subject to such settlement are characterized by fine-grained, frost-susceptible soils. Another potential problem related to extreme low temperature is frost-jacking, which can occur in wet fine-grained soils. Permafrost distribution and its characteristics within each study area were discussed in Section 3.2.3.

Flooding is caused most frequently by snowmelt, river ice jams, and heavy rainfall. Peak discharge on most rivers follows spring breakup of ice (Selkregg, 1976), and flooding often occurs when rainfall follows a period of warm weather that increases snowmelt. Areas most susceptible to flooding include the Glennallen study area along the Tazlina River, the Gulkana study area along the Copper River, and the Tok study area along the Tok and Tanana Rivers.

Volcanic hazards are associated with the dormant and active volcanoes in the Wrangell Mountains that lie about 62 miles from the nearest study area. Possible hazards include explosive eruptions, mudflows and slides, ashfalls, flash floods, and earthquakes. Only Mount Wrangell is known to have exhibited any recent activity; minor ash and steam plumes were noted in 1966, and temperatures around the North Crater warmed enough in 1974 to melt large quantities of ice (Yehle and Nichols, 1980). Ancient (more than 200,000 years ago) mudflows and avalanche deposits originating from the volcanoes in the Wrangell Mountains have been traced down the Chestaslina, Sanford, and Nadina River valleys.

Southcentral Alaska is part of a large, continuous, seismically active belt, where an earthquake of Richter magnitude 7 or greater is reported once every 10 years (Selkregg, 1974). All of the study areas lie within Seismic Zone 3, as designated by the Army Corps of Engineers. This zone indicates a maximum earthquake of greater than magnitude 6 and major damage to structures during a large seismic event.

The Copper River lowlands are surrounded by major fault systems; to the south lie the Border Ranges faults and to the north and east lies the long Denali Fault Zone. The Alaska Range and the upper Tanana River lowlands lie between the Denali Fault Zone and the Tintina Fault. Segments of the Denali Fault Zone are thought to have been active within the last 10,000 years (Richter and Matson, 1971; Stout et al., 1973). During the Great Alaskan Earthquake of March 27, 1964, the Glennallen-Gulkana area experienced up to 2 ft of subsidence, sustaining moderate structural damage.

Hazards created by seismic events may include ground cracking, scarp development, ground shaking, soil liquefaction, and slope instabilities.

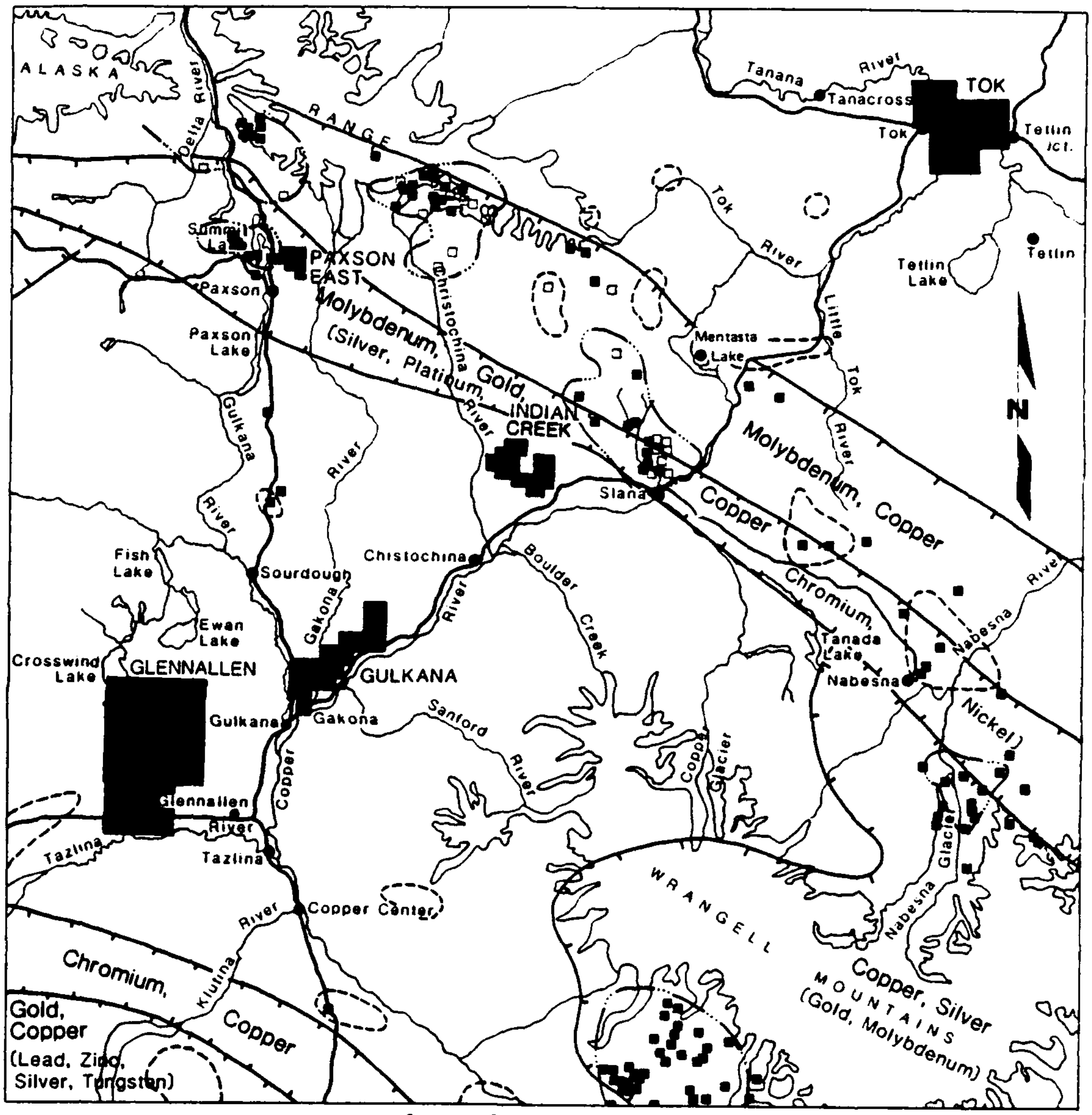
The Uniform Building Code (UBC) establishes the following four earthquake zones, which govern basic design criteria for man-made structures in these zones:

- UBC Zone No. 1--A magnitude 6 earthquake producing a peak acceleration of 0.1 g.
- UBC Zone No. 2--A magnitude 6 earthquake producing a peak acceleration of 0.2 g.
- UBC Zone No. 3--A magnitude 7 earthquake producing a peak acceleration of 0.3 g.
- UBC Zone No. 4--A magnitude 7 earthquake producing a peak acceleration of 0.4 g.

The Tok study area falls within Zone 1; Paxson East, Indian Creek, and Gulkana study areas are in Zone 2; and the Glennallen study area is in Zone 3.

3.2.5 Gravel and Minerals

The term "gravel" refers to deposits of coarse, granular material composed primarily of both sand and gravel. Minerals include metallic deposits, consisting of precious metals such as gold and silver; base metals such as lead, copper, molybdenum, and zinc (Figure 3-14); and nonmetallic deposits, including coal, geothermal sources, oil, and gas (Figure 3-15).



Source: Selkregg, 1974

0 10 20 30
Scale in Miles

0 10 20 30 40 50
Scale in Kilometers

Metal Provinces - Major and (Minor) Commodities Designated

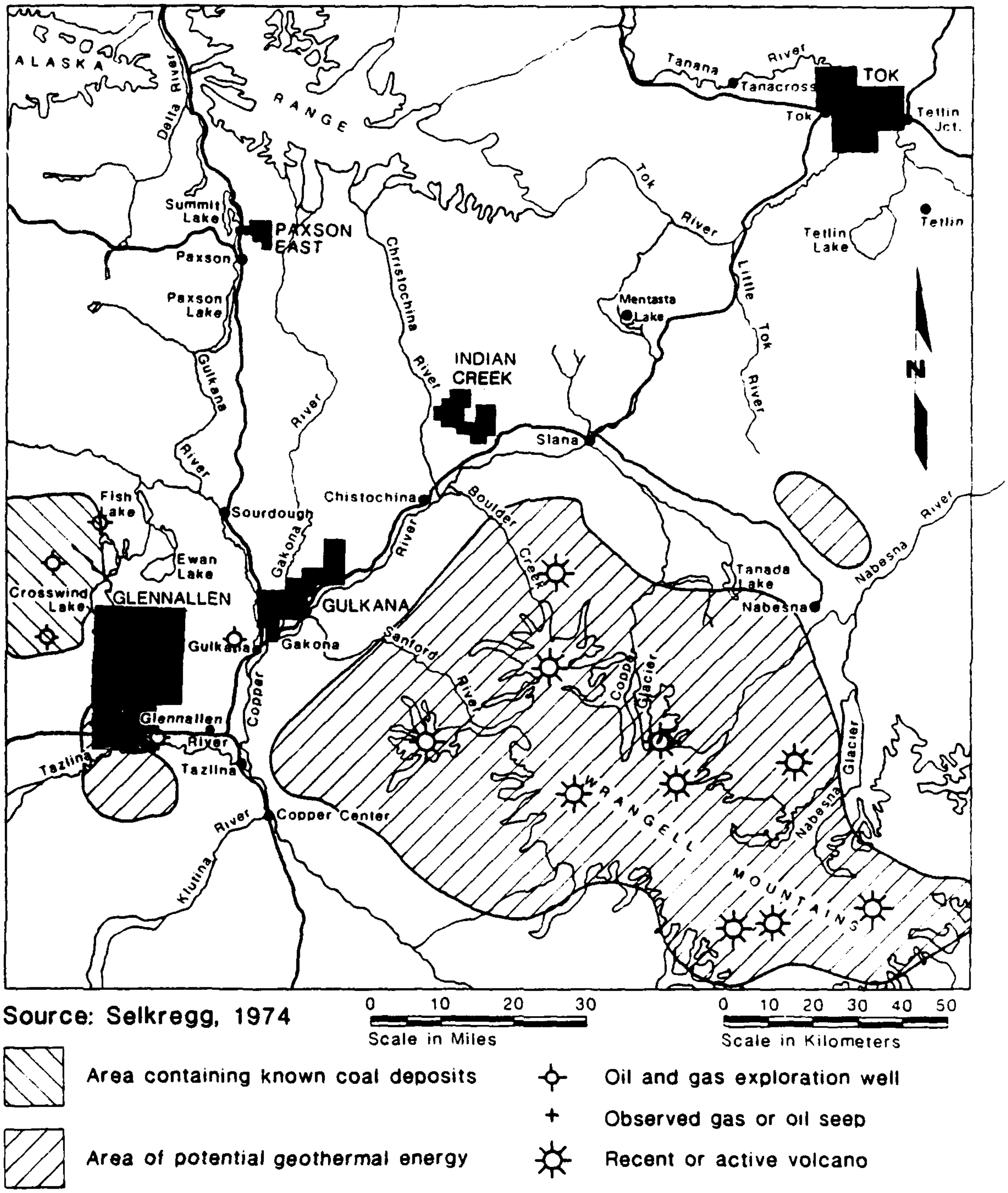
Intensive Mining Claim Activity Area

Moderate to Low Mining Claim Activity Area

■ Lode Deposit, Prospect or Mine

□ Placer Deposit, Prospect or Mine

FIGURE 3-14 REGIONAL METALLIC RESOURCES



Source: Selkregg, 1974

FIGURE 3-15 REGIONAL NON-METALLIC RESOURCES

Federal and state mining claims and current oil and gas leases have been identified along with state and federal material (borrow) site locations. Most of these material sites are located adjacent to the highway rights-of-way and have been used for road construction and maintenance, although some material sites in the Copper River basin were developed for the construction of the Trans-Alaska Pipeline.

3.2.5.1 Copper River Region

Information used to identify potential gravel sources includes maps prepared by the Alaska Division of Lands (ADL) and Division of Geological and Geophysical Surveys (DGGS), in conjunction with the Alaska Department of Transportation and Public Facilities (ADOT) for the Copper River Basin Area Plan. Existing material site locations also were identified through ADOT engineering geology and materials site investigation reports. BLM and ADL land status plats provide information on the land status of material sites.

Owing to the thickness of the overlying glacial material and the composition of underlying bedrock, metallic lode deposits are not important within most of the Copper River lowlands. Areas of minor importance may occur along the northern and eastern edges of the lowlands adjacent to the Alaska Range. No active, major mining of metallic lode deposits is known to occur at present, although placer gold deposits may occur along major upland rivers and streams.

Occurrences of petroleum, coal, and anomalous geothermal temperatures have been noted in the vicinity. The center of the Copper River lowlands around the towns of Glennallen and Gulkana has been designated the Copper River Petroleum Basin (Figure 3-15). Oil and gas seeps have been observed east of Glennallen, but exploratory wells developed throughout the area since 1956 have all been dry.

Known deposits of coal, discovered during exploratory oil drilling, exist within the thick section of Mesozoic rocks that underlie the lowlands. As currently defined, this coal region is approximately 25 miles long between Lake Louise and Crosswind Lake (Selkregg, 1974). No active coal mines are known to occur in the region.

The presence of the volcanically active Wrangell Mountains east of the Copper River lowlands provides the region with some geothermal energy potential. A portion of the lowlands west of the Wrangell Mountains and an area approximately 12 miles west of Glennallen have been designated as containing potential geothermal energy resources (Selkregg, 1974).

3.2.5.1.1 Glennallen Study Area

The Glennallen study area contains variably frozen, glacial-lacustrine deposits of silts, fine sands, and lesser amounts of clays overlain by a variable thickness of surficial organic soils and muskeg.

Some coarser-grained glacial, alluvial, and ancient beach deposits are located within the study area and may provide a source of borrow materials.

Although some known material sites and potential borrow areas have been identified near the study area (Figure 3-16), the Glennallen area itself is noted for a general lack of sand and gravel materials. Existing sources are used primarily for maintaining the Glenn Highway and have reached various stages of depletion. One pit, identified as critical by ADOT, has access problems due to private-property conflicts. Potential borrow sources identified by ADOT south and west of Glennallen are located on lands conveyed to Ahtna, Inc., and have not been investigated for available reserves or quality. The abundance of gravel resources in the Glennallen study area is expected to be low.

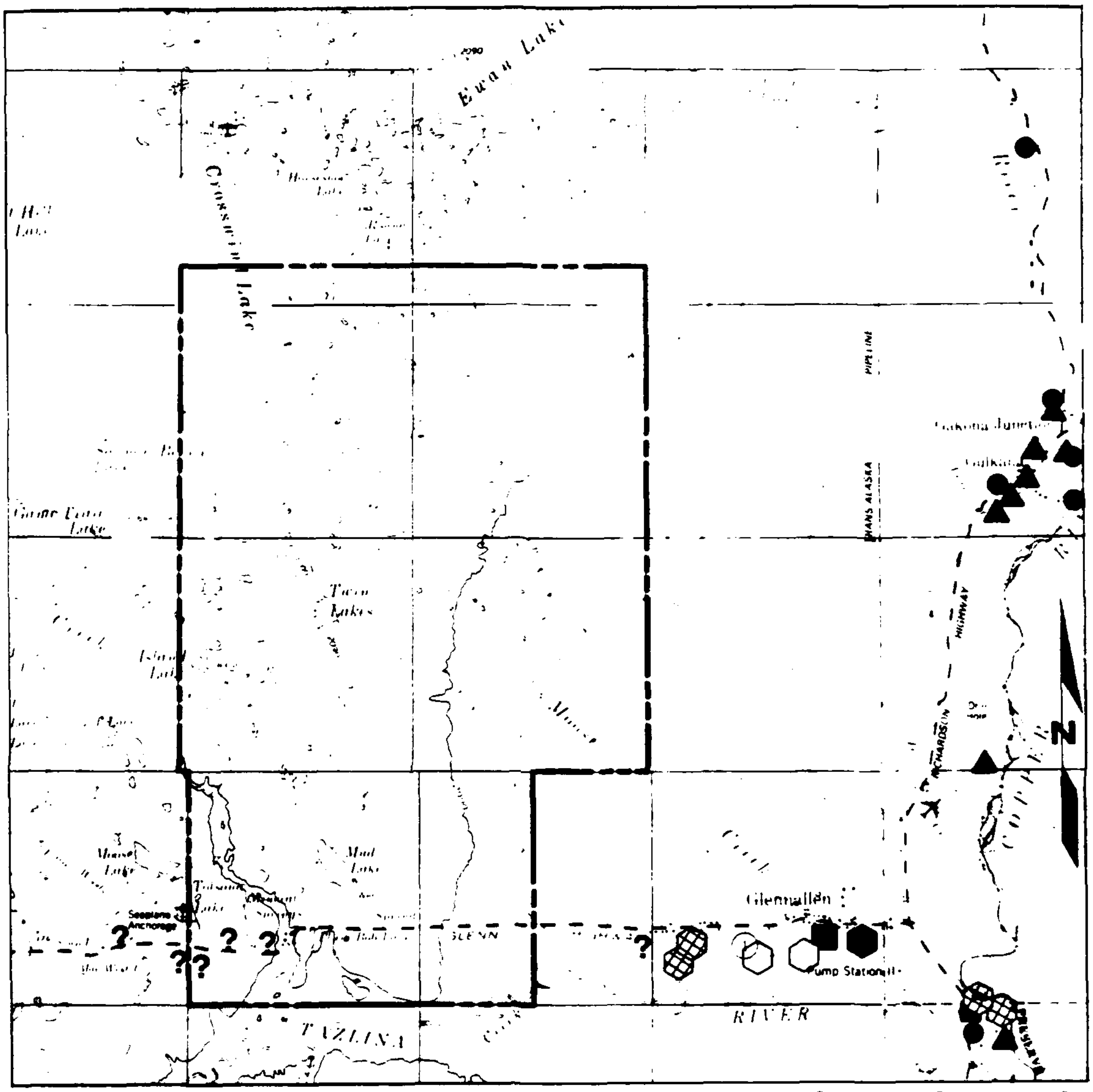
The Glennallen study area lies at the center of the Copper River Petroleum Basin. In 1957, the BLM classified the lands within the study area as potentially valuable for oil and gas exploration activities. Two natural seeps of oil, gas, or both occur within the southern part of the study area; however, no exploratory drilling has been conducted. The southern part of the study area has been designated as an area of potential geothermal energy on the basis of thermal scanner recordings. No metallic mineral or coal deposits are known to occur in the study area.

3.2.5.1.2 <u>Gulkana Study Area</u>

Subsurface conditions of the Gulkana study area can be characterized by variably frozen glacial-lacustrine silt, fine sand, and clay deposits overlain by a variable thickness of organic soils and muskeg. The Gakona and Gulkana Rivers meander through the study area within fairly well-defined drainage channels, which may contain deposits of sand and gravel. The Copper River is braided with numerous channels, sand bars, and inflowing streams, creeks, and rivers.

Figure 3-17 shows the distribution of existing material sites within the Gulkana-Gakona area. The Draft Copper River Basin Area Plan (Alaska Department of Natural Resources, 1986) has identified at least three material sites as critical for ADOT highway maintenance and construction along the Glenn Highway. The plan also identifies at least 10 privately owned material sites along both the Richardson and Glenn Highways in the Gulkana-Gakona area. These material sites have been characterized as thin terrace deposits and contain limited borrow materials. The abundance of gravel resources in the Gulkana study area is expected to be low.

The Gulkana study area lies within the Copper River Petroleum Basin. In 1957, the BLM classified land within the western portion of the study area as potentially valuable for oil and gas exploration activities. No exploratory drilling has been done within the study area, and the area contains no known occurrences of coal, metallic minerals, or potential geothermal energy.



Source: Alaska Department of Natural Resources, 1986

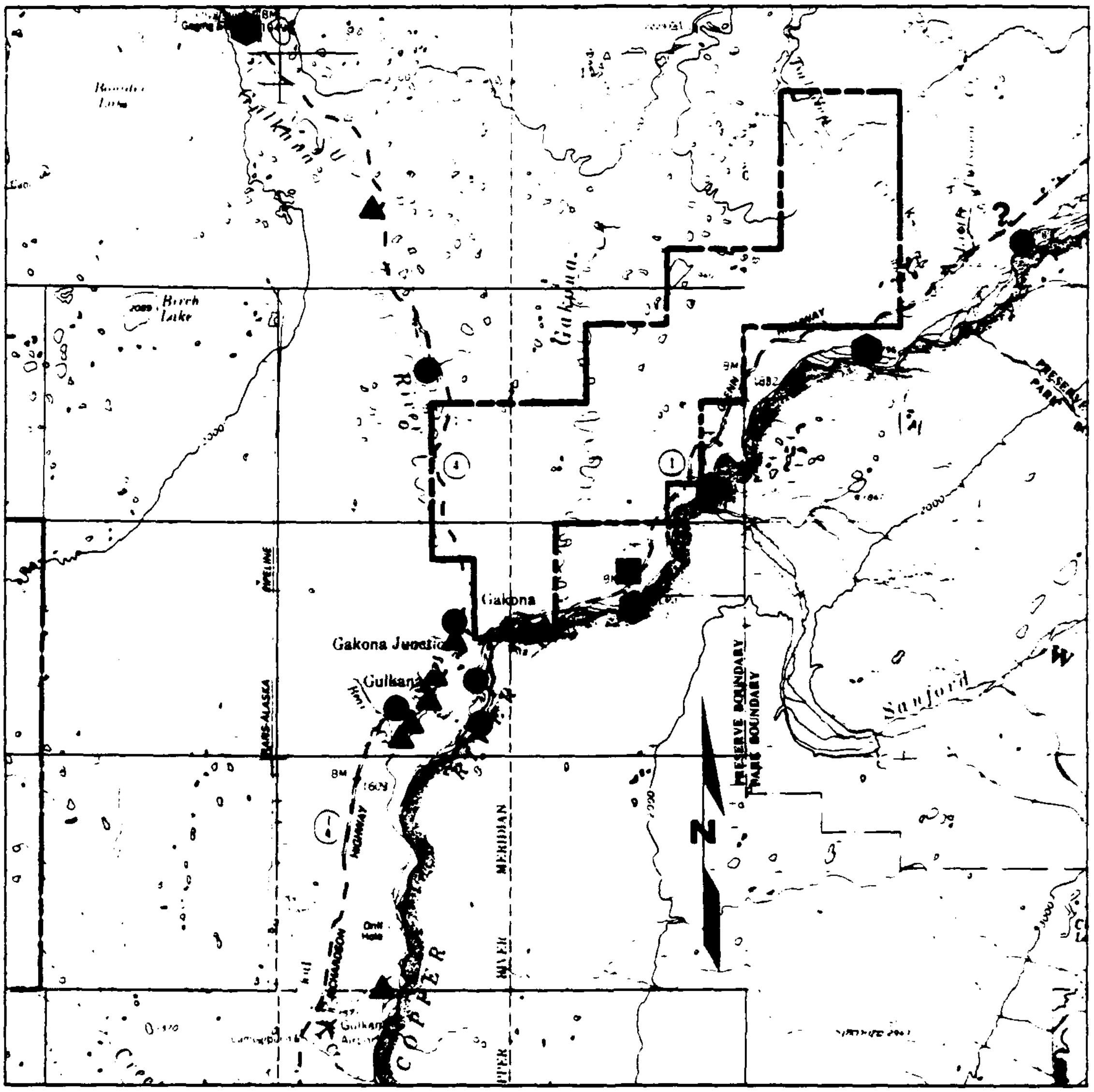
0 5
Scale in Miles

0 5 10
Scale in Kilometers

Sand and Gravel Material Site Location and General Land Ownership

⬢	A.D.O.T. Critical	▲	Private
⊗	A.D.O.T. High Potential Areas	■	State
●	Federal	?	Uncertain Status

FIGURE 3-16 GRAVEL AND MINERAL RESOURCES, GLENNALLEN STUDY AREA



Source: Alaska Department of Natural Resources, 1986

0 5 Scale in Miles

0 5 10 Scale in Kilometers

Sand and Gravel Material Site Location and General Land Ownership

- A.D.O.T. Critical
- A.D.O.T. High Potential Areas
- Federal
- Private
- State
- ? Uncertain Status

FIGURE 3-17 GRAVEL AND MINERAL RESOURCES, GULKANA STUDY AREA

3.2.5.1.3 Indian Creek Study Area

The Indian Creek study area is characterized by bedrock covered by a thin mantle of unconsolidated glacial and alluvial deposits in the eastern and western upland portions. The center of the study area appears to contain variably frozen glacial-fluvial terrace deposits of the Indian Creek drainage. The southern portion of the study area, containing a number of small lakes and tributaries to Indian Creek, is likely to be underlain by variably frozen, fine-grained, glacial-lacustrine deposits of silts and clays.

Figure 3-18 shows the locations of known material sites along the Glenn Highway corridor near the Indian Creek study area. The ADOT pit near the village of Indian River has been classified by the Copper River Basin Area Plan as critical for highway maintenance and construction. The plan also has identified an unexplored, possibly large sand and gravel borrow source area along the Glenn Highway near the southeastern border of the study area. The abundance of gravel resources in the Indian Creek study area is expected to be moderate.

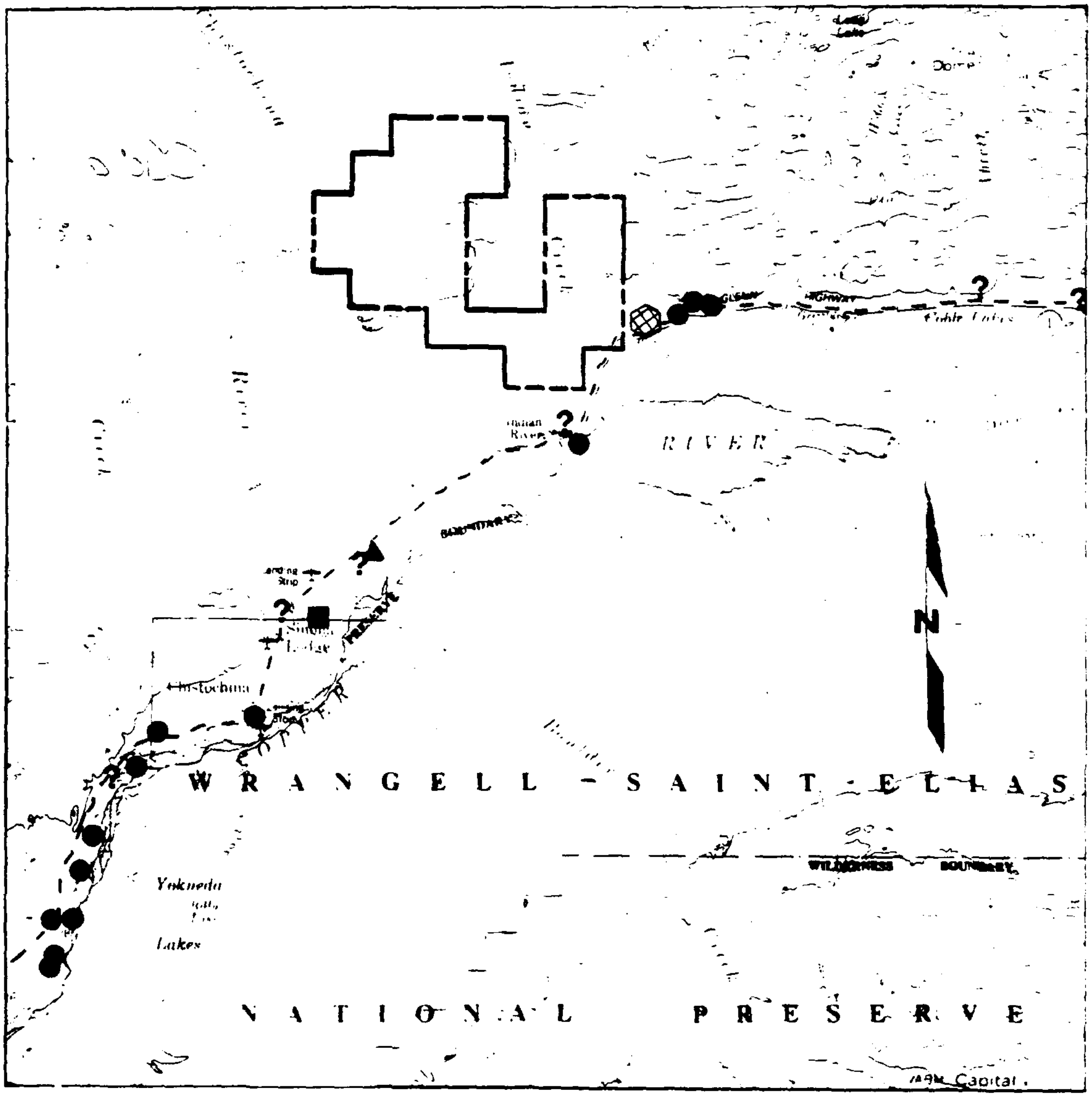
The Indian Creek study area lies outside the major mineral and metal terrains of the Alaska Range but has been the site of moderate to low mining claim activity (Selkregg, 1974). Placer deposits may occur along the creeks and streams within the study area; however, no active mines or occurrences of coal, petroleum, or geothermal energy are known.

3.2.5.2 Paxson East Study Area

Gravel occurrences within the Alaska Range are generally confined to terrace, floodplain, and channel deposits associated with the major rivers and streams. Owing to extensive mineralization, the central and eastern parts of the Alaska Range south of the Denali Fault System contain high to very high occurrences of metallic minerals (Selkregg, 1974). The Alaska Range can be divided into two main metal provinces, the Copper, Gold, and Silver Province to the west and the Copper, Gold, and Molybdenum Province to the east (Figure 3-14).

The Paxson East study area contains a northeast-southwest-trending, relatively flat ridge identified as a lateral moraine of the Gakona Glacier (U.S. Army Corps of Engineers, 1985). This ridge is composed of cobble and boulder till with mixtures of silts, sands, and gravels. Adjacent, well-drained ridge tops may provide borrow sources.

Figure 3-19 shows the distribution of known material sites in and adjacent to the Paxson East study area. Three ADOT-classified critical material sites are located near Paxson along the Richardson Highway, and five critical material sites lie along the Denali Highway, within 12 to 15 miles of the study area. Both ADOT and the Alyeska Pipeline Service Company have identified an area of potential sand and gravel resources from the north end of Summit Lake, along the east side of the Richardson Highway, to the Fish Creek valley. Abundant supplies of borrow material are anticipated to be available in this area.



Source: Alaska Department of Natural Resources, 1986

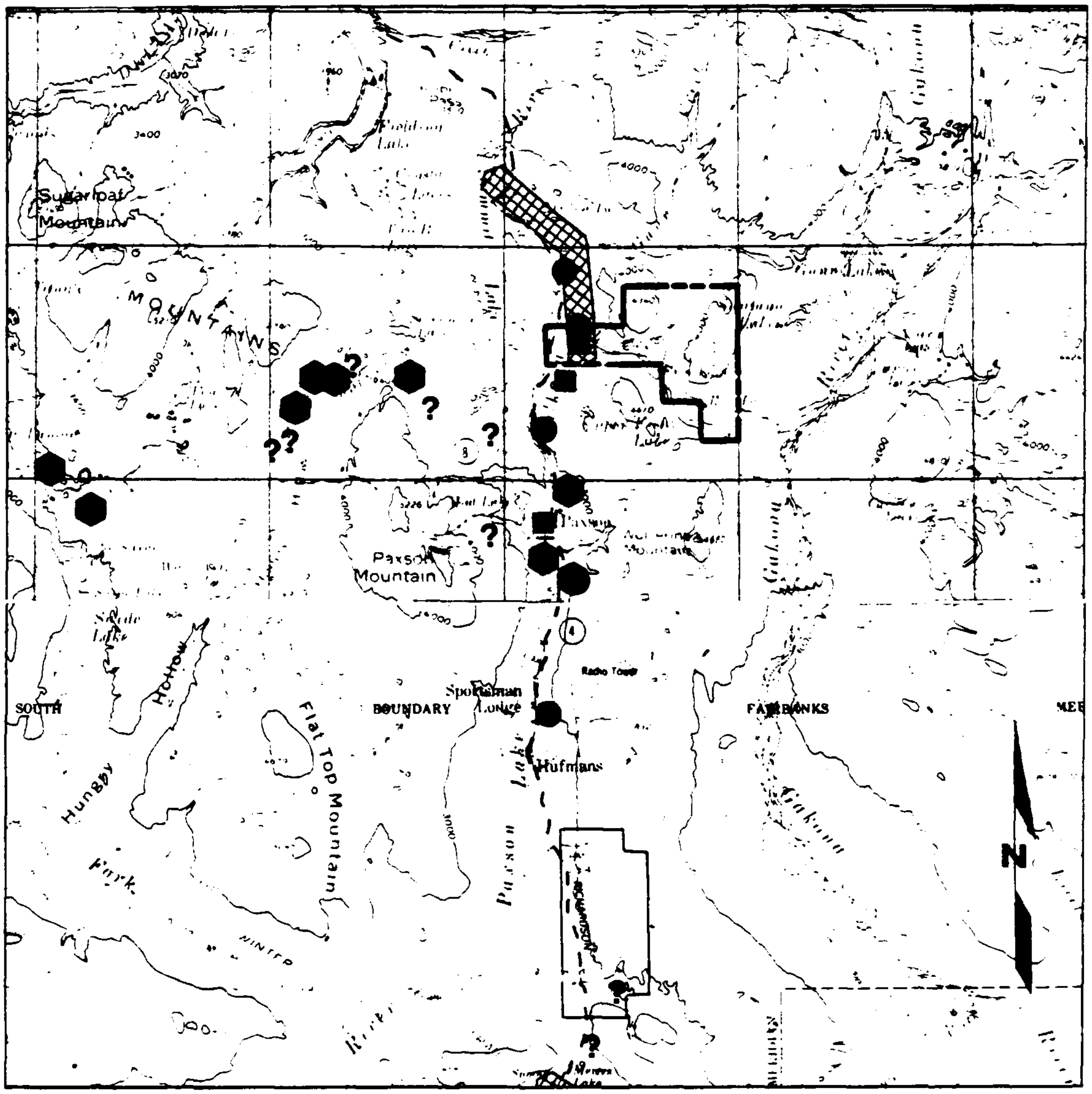
0 5
Scale in Miles

0 5 10
Scale in Kilometers

Sand and Gravel Material Site Location and General Land Ownership

- ⬢ A.D.O.T. Critical
- ⊗ A.D.O.T. High Potential Areas
- ● Federal
- ▲ Private
- ■ State
- ? Uncertain Status

FIGURE 3-18 GRAVEL AND MINERAL RESOURCES, INDIAN CREEK STUDY AREA



Source: Alaska Department of Natural Resources, 1986

0 5 Scale in Miles

0 5 10 Scale in Kilometers

Sand and Gravel Material Site Location and General Land Ownership

- A.D.O.T. Critical
- A.D.O.T. High Potential Areas
- Federal
- Private
- State
- ? Uncertain Status

FIGURE 3-19 GRAVEL AND MINERAL RESOURCES, PAXSON EAST STUDY AREA

The Paxson East study area occurs within the Copper, Gold, and Molybdenum Province of the Alaska Range. Accessory minerals also found within this province are platinum, chromium, and nickel. No prospects or mines are known within the study area, although the western portion contains extensive mining claims. No occurrences of coal, petroleum, or geothermal energy are known within the study area.

3.2.5.3 Tok Study Area

The Tok study area lies within the Tanana River floodplain, where landforms consist of granular floodplain deposits, alluvial fans, and dissected terrace deposits. Borrow materials, consisting of sand and gravel, have been identified at shallow depths and are expected to occur in abundant quantities in the study area (U.S. Army Corps of Engineers, 1985). Figure 3-20 shows the approximate locations of federal and state highway material sites in and near the study area.

No significant metallic or nonmetallic occurrences are known in the upper Tanana River Lowlands, the bedrock areas to the north and south, or the Tok study area.

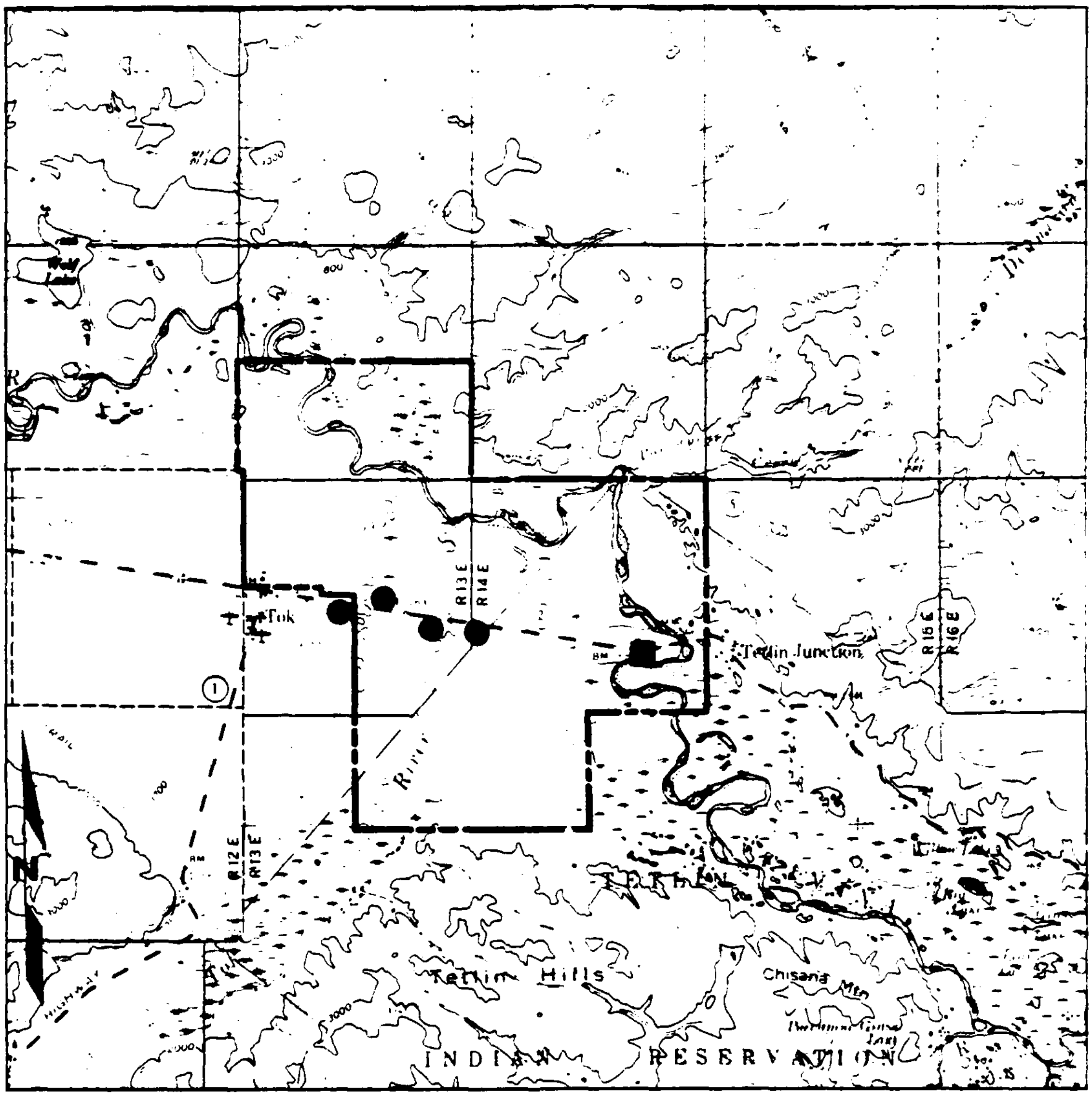
3.3 Vegetation

The vegetation of the study region is a component of the northern boreal forest, or taiga, which covers some 106 million acres of Alaska (Viereck, 1973). Within this study region, forests are bounded at higher elevations by alpine tundra, ice, and snow, and at lower elevations by streams, rivers, lakes, and muskeg bogs. Forest composition is generally homogeneous across large areas but can vary considerably between local sites as a result of slope, aspect, permafrost, fire history, and water availability. Black-spruce-dominated associations are very common in the northern boreal forest and frequently indicate a wetland, permafrost, or a prior fire.

3.3.1 Habitat Characteristics

The study region's climate is characterized by extreme temperatures, low precipitation, and light surface winds (Selkregg, 1976; Wise, 1986). The frost-free growing season in this part of Alaska lasts only about 7 weeks, from about mid-June to early August. The total growing season is about 11 weeks long (Selkregg, 1976).

Permafrost is common on north-facing slopes and in valley bottoms that receive little solar radiation (Brown and Pewe, 1973). Permafrost underlies an active surface layer that freezes and thaws each year. Permafrost influences plant growth by impeding root penetration and through a general cooling of the active layer. Growth of all species is slower over permafrost; detrital decomposition also is slowed in comparison with permafrost-free areas. Permafrost also impedes percolation of rainfall and snowmelt water; consequently, overlying soils are often very moist.



Source: Alaska Department of
Natural Resources, 1986

0 5
Scale in Miles

0 5 10
Scale in Kilometers

Sand and Gravel Material Site Location and General Land Ownership

⬢	A.D.O.T. Critical	▲	Private
⊗	A.D.O.T. High Potential Areas	■	State
●	Federal	?	Uncertain Status

FIGURE 3-20 GRAVEL AND MINERAL RESOURCES, TOK STUDY AREA

Natural and man-made fires are common to the northern boreal forest, and many plants are fire adapted. The fire season in the study region occurs between April 1 and September 30; however, most fires occur between May and July (Barney, 1967). Before widespread fire fighting efforts began in 1940, wildfires burned an estimated 1 million (Lutz, 1953) to 2.5 million acres (Barney, 1971) each year in Alaska. Since then, the area burned each year has been roughly one-third to one-half of the historic record, although fire frequency has increased. Fire occurrence in interior Alaska centers mainly on tundra, bog, and non-commercial forest stands of black spruce (Foote, 1983).

3.3.2 Vegetation Associations

3.3.2.1 Riparian

Riparian associations are those occurring along rivers or other bodies of water. On relatively dry sites below about 2,000 ft elevation, such associations often are dominated by mixed to pure stands of white spruce and balsam poplar. Paper birch and aspen also may be present; the former is usually absent from north-facing slopes, and the latter is generally found only on south-facing slopes. Understory vegetation is relatively diverse and may include willow, prickly rose, devil's club, alder, raspberry, blueberry, highbush cranberry, grasses, and ferns.

Wetter riparian communities and associations, such as occur in floodplains and bordering marshes, usually are dominated by black spruce and balsam poplar; understory vegetation is usually relatively simple and often consists of pure stands of Labrador tea, horsetail, or mosses.

3.3.2.2 Upland Forests

Upland forests of the region generally consist of well-mixed stands of aspen, paper birch, and white and black spruce. The aspen stands are typically found on south-facing slopes in association with a relatively tall understory (3 to 5 ft) composed of prickly rose and highbush cranberry. The tree line for aspen in this area is typically at about 2,000 ft elevation. Aspen grow in the warmest forest sites in interior Alaska, generally on slopes between 7° and 40° (Foote, 1983; Viereck and Little, 1972). Communities of this type in interior Alaska usually mature between 50 and 80 years of age. Herbaceous vegetation in this type of association usually is dominated by horsetail, bunchberry, and fireweed.

Birch stands occur to about 2,000 ft elevation, mainly on east- and west-facing slopes; however, they can replace aspen on disturbed southern aspects as well. These stands are considered mature when the birch is between 50 and 130 years old (Foote, 1983). As in the aspen associations, the taller understory is composed chiefly of prickly rose and highbush cranberry; alder also is present and may reach heights of 7 to 13 ft.

White spruce occurs in the following two distinct associations within the upland forest type: a white spruce, highbush cranberry, horsetail, and feathermoss association; and a white spruce, prickly rose, horsetail, and feathermoss association. The first type occurs mainly on south-facing slopes to about 2,000 ft elevation. Age at maturity is unclear; when trees are 100 to 200 years old, the community is somewhat open and dominated by large trees. The understory is dominated by prickly rose and highbush cranberry with occasional clumps of green alder.

The white spruce, horsetail, prickly rose, and feathermoss association is characterized by a closed canopy, an extensive and relatively closed understory dominated by prickly rose, an almost contiguous mat of feathermoss, and extensive patches of horsetail. This type, which is most common on river islands, is the most productive timber stand in interior Alaska (Hutchison, 1968; Viereck and Little, 1972). The understory includes prickly rose, highbush cranberry, feathermoss, and wintergreen.

Six types of black-spruce-dominated associations occur in the upland forest of the study region. The black spruce-aspen-bunchberry type occupies relatively warm (south-facing) slopes and well-drained soils. Both dominant tree species reach maturity in 60 to 70 years. The understory consists chiefly of prickly rose, with scattered growths of green alder and Bebb willow.

The second black spruce type is dominated by black spruce, paper birch, blueberry, and Labrador tea. Mature stands of this type are characterized by a closed canopy of black spruce and paper birch, a discontinuous understory of mountain cranberry, Labrador tea, bog blueberry, and a developing cover of feathermoss. This association occupies mesic sites on slopes of all aspects and also occurs on poorly drained valley bottoms.

The third black spruce type is dominated by black spruce, bog blueberry, Labrador tea, and feathermoss. This type also occupies slopes and valley bottoms where ice-rich permafrost is usually present. Understory vegetation is discontinuous and poorly developed, mostly because of the cooling influence of the permafrost, but is dominated by Labrador tea, bog blueberry, mountain cranberry, and prickly rose.

The fourth black spruce type is dominated by black spruce and feathermoss. In mature stands of this type (40 to 70 years old), lichen-dominated openings separate the black spruce trees, which frequently occur in small, dense clumps. This type can occur wherever spruce occurs; permafrost may or may not be present.

The fifth black spruce type is dominated by black spruce, white spruce, resin birch, and lichens. Stands of this type occupy east- or west-facing slopes near timberline. Understory vegetation is composed of resin birch, mountain cranberry, bog blueberry, Labrador tea, <u>beauverdiana</u> spirea, and lichens.

The last black spruce type is dominated by black spruce, sphagnum, and Cladina lichens. Stands of this type occur on wet sites in valley bottoms and on north-facing slopes where ice-rich permafrost is present. Species found here are tolerant of the cooling effect of the underlying permafrost and include tussock cotton grass, leatherleaf, sedges, bog cranberry, Labrador tea, diamond leaf willow, crowberry, and cloudberry.

3.3.2.3 Scrub

Extensive scrub associations occur throughout the region, but especially near timberline. At tree line, the chief plant is often alder. In such associations, the understory is a complex mix of grasses, sedges, mosses, lichens, ferns, and small shrubs.

Low-lying scrub associations occur in avalanche chutes, floodplains, recently burned sites, and similarly disturbed areas. Alder dominates sites where mineral soils have been exposed. The understory in such sites is often simple, consisting of sparse grasses, lichens, and mosses.

3.3.2.4 Alpine

Alpine areas of the study region support a wide array of vegetation types ranging from low and dwarf scrub to herbaceous graminoid, forb, bryoid, and aquatic communities. Immediately above tree line a transition zone of low and dwarf scrub often occurs. Dominant plants of this association are usually resin birch, soapberry, stunted alder, blueberry, and willows of several species. Understory vegetation ranges from contiguous mats of grasses and sedges to cranberry and bearberry.

Alpine herbaceous meadows occur from timberline to the limits of permanent snow and ice, becoming more common with increasing altitude. Community composition varies from pure stands of sedges to sphagnum and lichens.

3.3.2.5 Wetlands

The term "wetlands" includes bogs, swamps, marshes, and similarly wet lands that have been grouped into one category, primarily for the purpose of environmental management. The U.S. Fish and Wildlife Service characterizes wetlands as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water" (Cowardin et al., 1979). The definition of wetlands used by the U.S. Army Corps of Engineers, which has regulated the dredging and filling of wetlands since 1977, is:

> Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions.

Wetlands are complex systems and generally represent an important resource. They provide resting and breeding grounds for birds and spawning and rearing habitat for fish. Wetlands regulate the flow of water in streams, absorbing water in wet seasons and discharging it in dry seasons. They can improve water quality by allowing solid particles to settle and by absorbing nutrients. Wetlands can also protect shorelines from erosion, facilitate recharge of groundwater aquifers, and provide people with recreational and educational opportunities.

Wetland vegetation associations of the region are fairly complex and widely distributed, and appear to be dominated by either sphagnum, aquatic sedges, or black spruce (U.S. Fish and Wildlife Service, 1986; Spetzman, 1957-1963; Batten and Murray, 1982).

Sphagnum-dominated associations often include small shrubs such as bog blueberry and dwarf birch, as well as scattered clumps of aquatic sedges. They may be found at all elevations up to permanent snow line.

Sedge-dominated wetlands occur as near-contiguous mats of one type (e.g., Eriophorum spp.) with scattered occurrences of others (e.g., Carex spp.). The wetland often is bordered by dwarf shrubs such as resin birch. These, too, may be encountered at all elevations up to permanent snow line.

Black-spruce-dominated wetlands are very common in the study region. They usually occur as nearly pure stands of black spruce with an understory of Labrador tea and, possibly, lowbush cranberry.

In Alaska, the identification of wetlands is often difficult because of the severe climate. Plants that survive in Alaska have generally developed brood tolerances to the characteristically moist soil conditions. Thus, some plants typically found in wetlands, such as black spruce, may also be found in upland (nonwetland) areas.

3.3.3 Successional Trends

Several major factors influence succession, including the type of seedbed available, vegetation community present before disruption, seed and propagule sources, degree of disruption, and climatic and weather conditions. Seedbed type is one of the most influential. If the exposed soil has a large component of unweathered parent material and has never supported plant life (a common postglacial situation in Alaska), the invasion and development of vegetation associations is called primary succession. In secondary succession, the seedbed has previously supported vegetation, which may have been destroyed by such forces as fire, cultivation, or timber harvest. The soil, including humus remains, and some residual plants, propagules, or seeds usually are present (Daubenmire, 1968). The type of succession influences the types of associations and the rate of replacement that occur within a given community.

In the five study areas, primary succession occurs on landslides, talus slopes, cliffs, mountaintops, recently glaciated areas, lakeshores, streambeds, and associated gravel deposits. Although plant growth in some of these areas may be limited, other areas may become well vegetated in less than 50 years (Holmes, 1981).

The types of areas that support secondary succession include avalanche chutes, burns, bladed roads, blowdowns, and any other surface perturbation in previously vegetated areas. Succession may be limited by the physiological limits of plant growth, environmental conditions, substrate, and propagule sources. Severe disturbances that remove and compact the soil and destroy most of the previous vegetation (avalanches, road grading, etc.) take the longest to recover. Invading species in such areas often are fireweed, lupine, and alder.

Fire may leave many plants essentially unharmed or may destroy all above-ground plant tissue. It rarely destroys all roots and underground propagules, which often send up shoots within a year. Fireweed and black spruce typically dominate severely burned forest sites.

3.3.4 Endangered Species

Currently, no indigenous Alaska plant species are listed by the U.S. Fish and Wildlife Service as threatened or endangered; however, 30 species have been proposed as candidates by the U.S. Forest Service for addition to the federal list (Federal Register, 1983). All of these are "Category 2" species, defined as "Taxa for which information... indicates the probable appropriateness of listing as endangered or threatened, but for which sufficient information is not presently available to...support a proposed rule." Since 1980, the USFWS has been seeking volunteer information on the subject species to define their status better.

Three of the 30 candidate species have range distributions that include the study region. *Montia bostockii* is known to inhabit wet, alpine sedge-grass-forb meadows and the moist centers of frost scars of the northern St. Elias Mountains, the easternmost Wrangell Mountains, and the Yukon-Tanana upland (Murray, 1980). Because of fairly broad distribution in alpine areas of eastern Alaska, it could occur within the Indian Creek and Paxson East study areas. *Smelowskia borealis villosa* is known to inhabit a few high-elevation slopes of the Alaska Range (Murray, 1980). This plant has been described from only three locations, and its apparent affinity for mountain summits diminishes the likelihood of its presence in any of the study areas. *Taraxacum carneocoloratum* is a conspicuous dandelion having deep pink to flesh-colored flowers. The taxon has been found only at Denali National Park and Preserve and in the Ogilvie Mountains of the Yukon Territory in Canada; it occupies alpine slopes and coarse, well-drained substrates (Murray, 1980). Because of its general distribution and habitat requirements, it could occur in the Indian Creek and Paxson East study areas.

3.3.5 Glennallen Study Area

Spetzman's (1957-63) cover type maps indicate that a complex of vegetation associations exist in the Glennallen study area, including all the types discussed previously except for alpine associations. Miracle (1986) reported that some commercial stands of white spruce occur in this area (one nearby sale averaged 12,000 board feet per acre) but that black spruce associations are the predominant types present. He estimated that, if clearcut, the black spruce associations might yield an average of 10 cords of firewood per acre.

Wetlands are widespread in the area and appear to be predominantly of a type classified by the USFWS as palustrine. Cowardin et al. (1979) defined palustrine systems as those traditionally known by such names as shallow pond, marsh, swamp, bog, and fen. Palustrine wetlands are typically situated shoreward of lakes and riverbeds in isolated catchments and occasionally on slopes.

The USFWS (1986) has conducted a wetlands inventory in selected areas near Glennallen. This inventory indicates that at least 90% of T.5N. R.3W., 50% of T.4N. R.4W., and 50% of T.5N. R.4W. of the Gulkana Quadrangle are Palustrine; these three townships occupy the southern portion of the Glennallen study area.

3.3.6 Gulkana Study Area

Interpretation of Spetzman's (1957-63) cover type maps indicates that the Gulkana study area is similar to the Glennallen study area. Miracle (1986) stated that black spruce associations dominate this area; if clearcut, the area might yield an average of 8 cords of firewood per acre.

3.3.7 Indian Creek Study Area

Interpretation of Spetzman's (1957-63) original cover type maps indicates that the western ridges of the Indian Creek study area support a type of upland spruce forest and both scrub and herbaceous tundra associations. Miracle (1986) believes that black spruce associations dominate the forest types here. The eastern ridges support dwarf alpine scrub and a transitional zone between an upland-forest type and the alpine types. Wetlands may also occur in areas of low relief.

3.3.8 Paxson East Study Area

On the basis of Spetzman's (1957-63) original cover type maps and an Army Corps of Engineers (1985) reconnaissance survey, the study area supports primarily a mixture of low and dwarf scrub, with the latter dominating. Vegetation types include a mixture of dryas, ericaceous heath, and dwarf willow scrub, with extensive barren areas interspersed throughout. Small, wet, contiguous herbaceous meadows and slope bogs occur as well.

3.3.9 Tok Study Area

On the basis of Spetzman's (1957-63) original cover type maps and an Army Corps of Engineers (1985) reconnaissance survey, the Tok study area probably supports a combination of riparian and upland forest types corresponding to those described earlier. Wetlands occur throughout the study area.

3.4 Wildlife

3.4.1 Fish

This section groups the fish to be discussed into two types: anadromous and nonanadromous. Anadromous fish are those that live most of their lives in the sea but travel up rivers for breeding. Nonanadromous fish are those that spend their entire lives in essentially the same aquatic environment.

Water bodies within the Copper River basin study areas contain lake trout and rainbow trout, as well as various other species of fish. By contrast, the Tok study area, which lies north of the Alaska Range, is characterized by the presence of several species of whitefish but, more conspicuously, by the absence of rainbow trout and lake trout. The major species of anadromous and nonanadromous fish known to be present in each study area are listed in Table 3-1, and their distributions within and near each study area are shown in Figures 3-21 to 3-25.

Anadromous salmon, whitefish, Arctic grayling, burbot, and Dolly Varden/Arctic char are common to all the study areas. Dolly Varden/ Arctic char is a species complex consisting of both *Salvelinus malma* and *S. alpinus*; it is referred to as "char" because the taxonomic status of the species is undecided, and the Alaska Department of Fish and Game (ADF&G) has adopted this terminology.

3.4.1.1 Anadromous Fish

3.4.1.1.1 Copper River Basin

The Copper River is the major migratory route for anadromous salmon and steelhead bound for habitats in the four study areas south of the Alaska Range. Sockeye salmon are the most abundant salmon species in the basin, followed by coho and chinook in much smaller numbers. The Glennallen, Gulkana, and Indian Creek study areas contain all three species of salmon plus steelhead, while the Paxson East study area contains only sockeye salmon.

Chinook salmon enter fresh water from early June through mid-August and spawn predominantly from late July through early August in rivers or tributaries. Coho are present in fresh water from mid-August until late

Table 3-1

FISH PRESENT IN THE FIVE STUDY AREAS

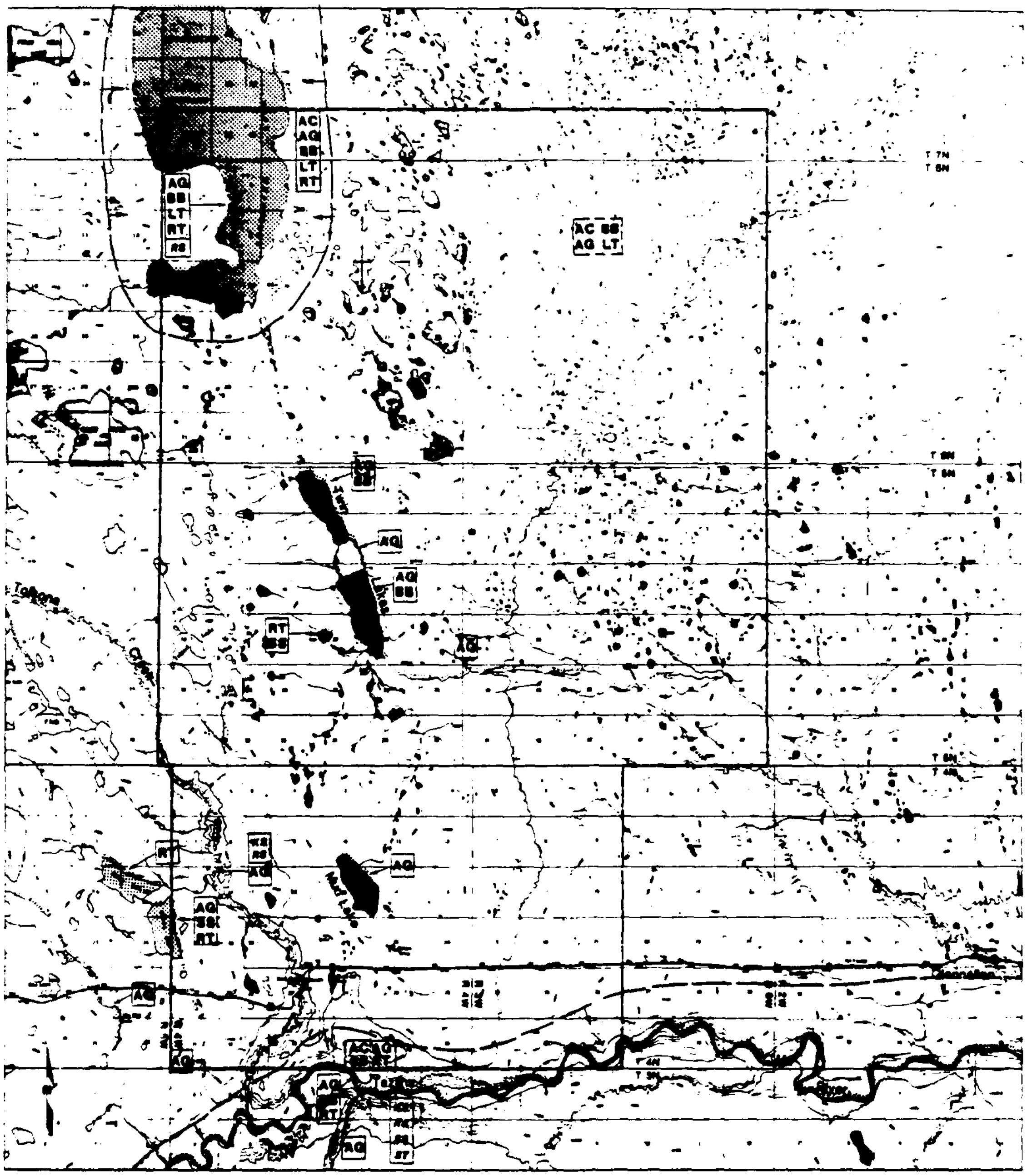
Species	Glennallen	Gulkana	Indian Creek	Paxson East	Tok
Anadromous[a]					
Chinook salmon	+	+	+		+
Chum salmon	+	+	+		+
Coho salmon	+	+	+		+
Sockeye salmon	+	+	+	+	+
Steelhead trout	+	+	+		
Nonanadromous					
Artic grayling	+	+	+	+	+
Burbot	+	+	+	+	+
Char	+	+	+	+	+
Humpback whitefish					+
Lake trout	+	+	+	+	
Rainbow trout	+	+	+	+	
Round whitefish					+
Northern pike					+
Sheefish (inconnu)					+

[a]Anadromous fish are those that swim upstream from the sea to spawn.
Source: ADF&G, 1986b.

January; peak spawning occurs in tributaries from early September until mid-October (ADF&G, 1986a). Eggs of both species incubate through the winter, and fry emerge the following spring. Juveniles spend one or more years in fresh water prior to migration as smolts.

Sockeye salmon enter fresh water from late May through July. Spawning occurs in lakes, streams, sloughs, and springs; it peaks from early July through late October. Fertilized eggs mature over the winter, with emergence occurring the following spring. Juvenile fish generally move to a lake for 1 or 2 years of residence, although some stream-resident sockeye juveniles occur in the area (ADF&G, 1986b). The juveniles migrate out of the system during the summer.

Steelhead trout are found in the Gulkana River (ADF&G, 1978), which may constitute their northernmost distribution in North America (ADF&G, 1986a). Steelhead in the Copper River system are fall-run fish, entering the Tazlina or Gulkana Rivers then. They overwinter in the lower reaches of these rivers and spawn from late May through mid June (Burger et al., 1983). Fertilized eggs incubate from 4 to 7 weeks (Morrow, 1980), although development time depends on water temperature. Juveniles remain



Source: ADF&G. 1986c

AG BB	Species present	
	River corridor within which species may be present	
AC	Area outside corridor within which species may be present	

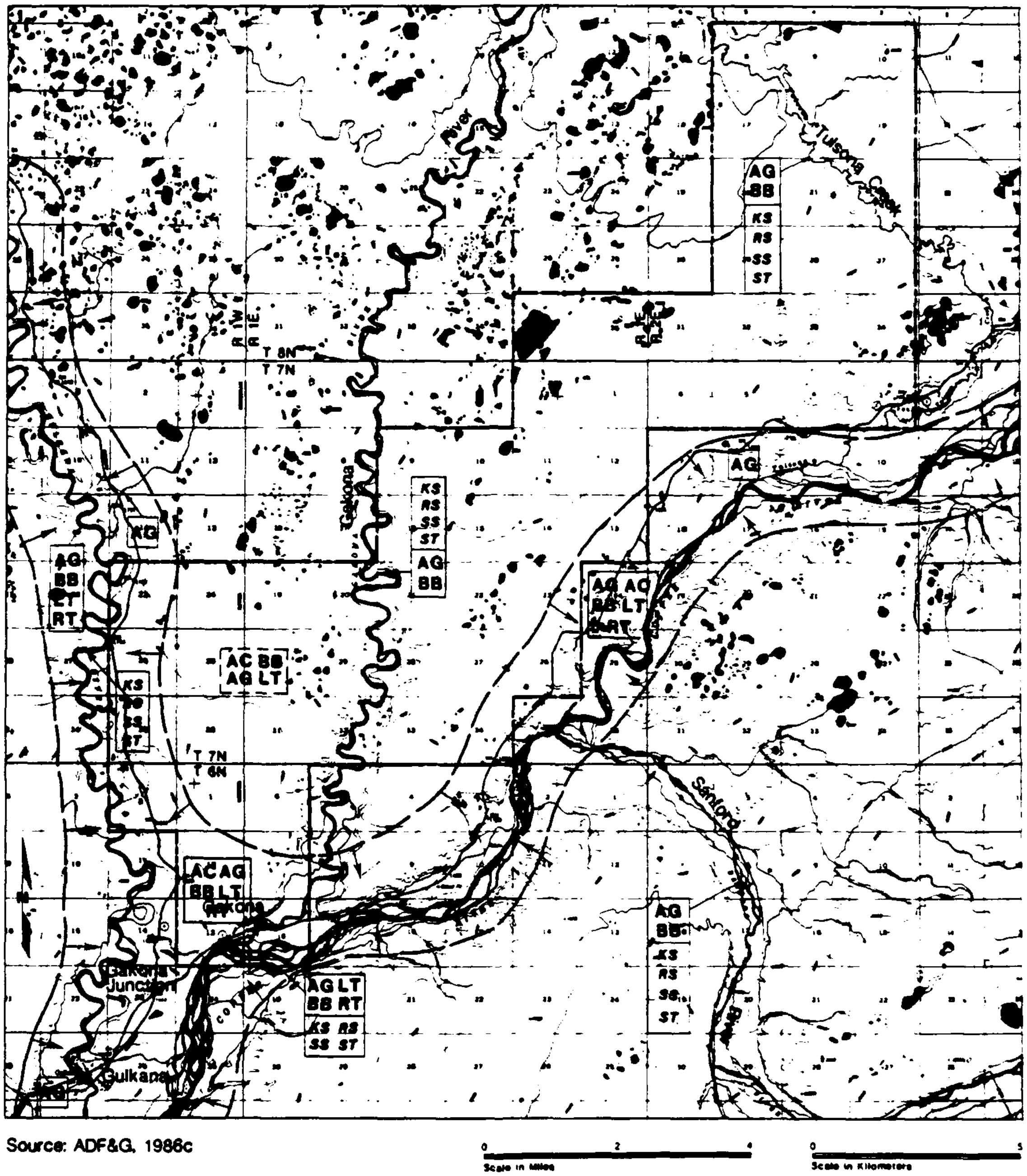
Non-Anadromous Species

- AG Arctic grayling
- AC Char
- RT Rainbow trout
- LT Lake trout
- BB Burbot

Anadromous Species

- KS Chinook salmon
- RS Sockeye salmon
- SS Coho salmon
- ST Steelhead Trout

FIGURE 3-21 FISH DISTRIBUTION, GLENNALLEN STUDY AREA



Source: ADF&G, 1986c

RT LT	Species present	
	River corridor within which species may be present	
AC BB	Area outside corridor within which species may be present	

Non-Anadromous Species		Anadromous Species	
AG	Arctic grayling	KS	Chinook salmon
AC	Char	RS	Sockeye salmon
RT	Rainbow trout	SS	Coho salmon
LT	Lake trout	ST	Steelhead trout
BB	Burbot		

FIGURE 3-22 FISH DISTRIBUTION, GULKANA STUDY AREA

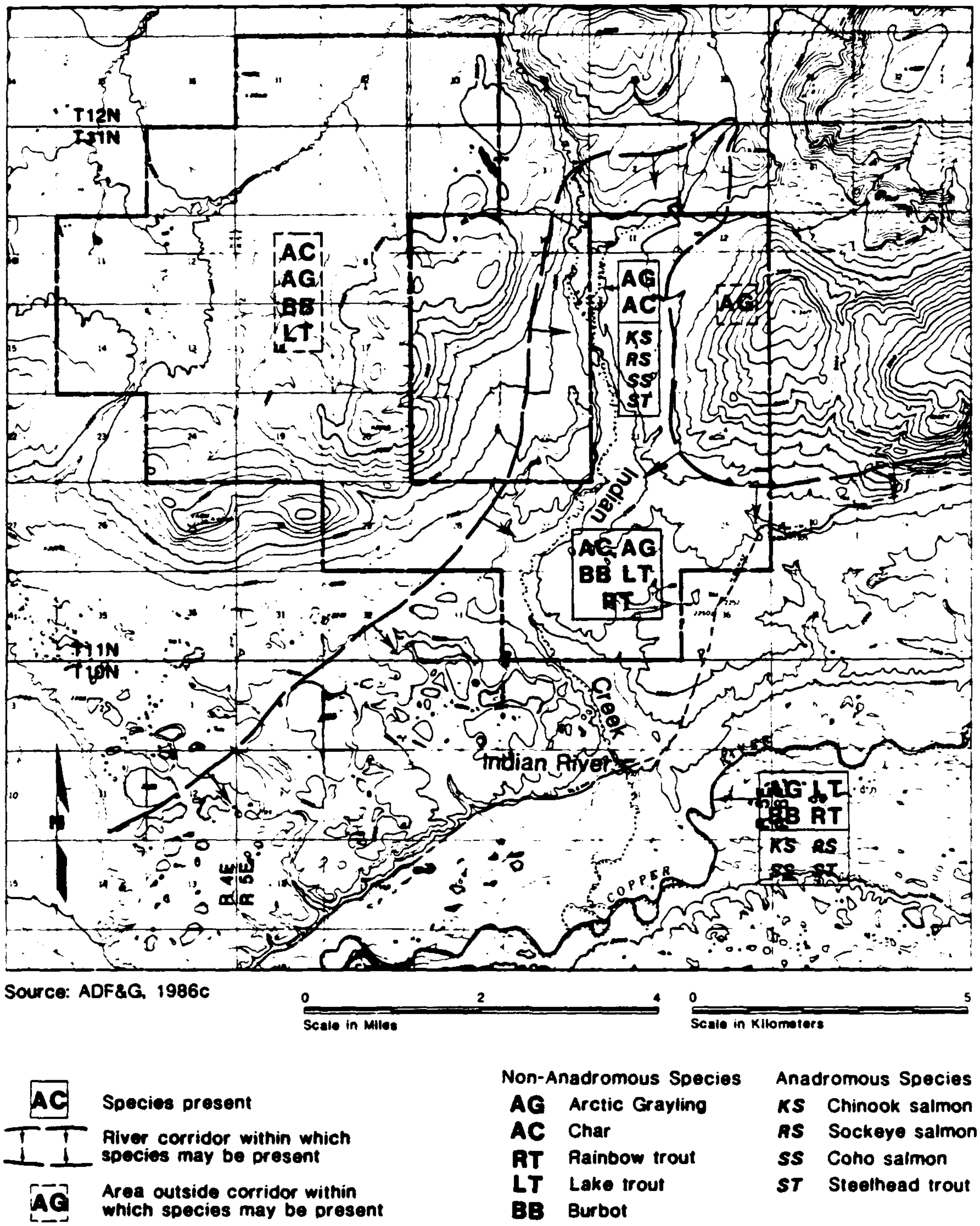
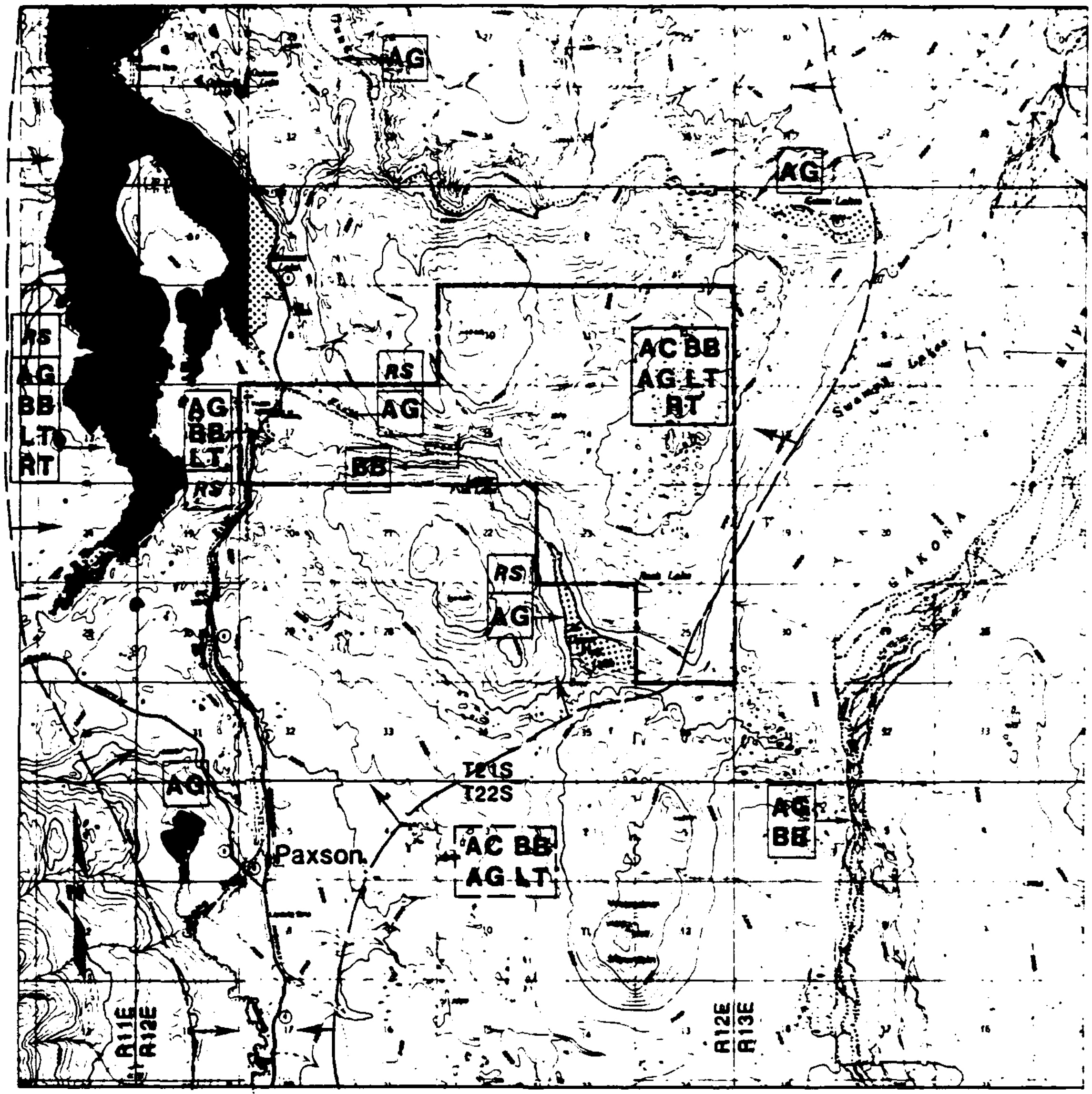


FIGURE 3-23 FISH DISTRIBUTION, INDIAN CREEK STUDY AREA



Source: ADF&G, 1986c

0 2 4
Scale in Miles

0 5
Scale in Kilometers

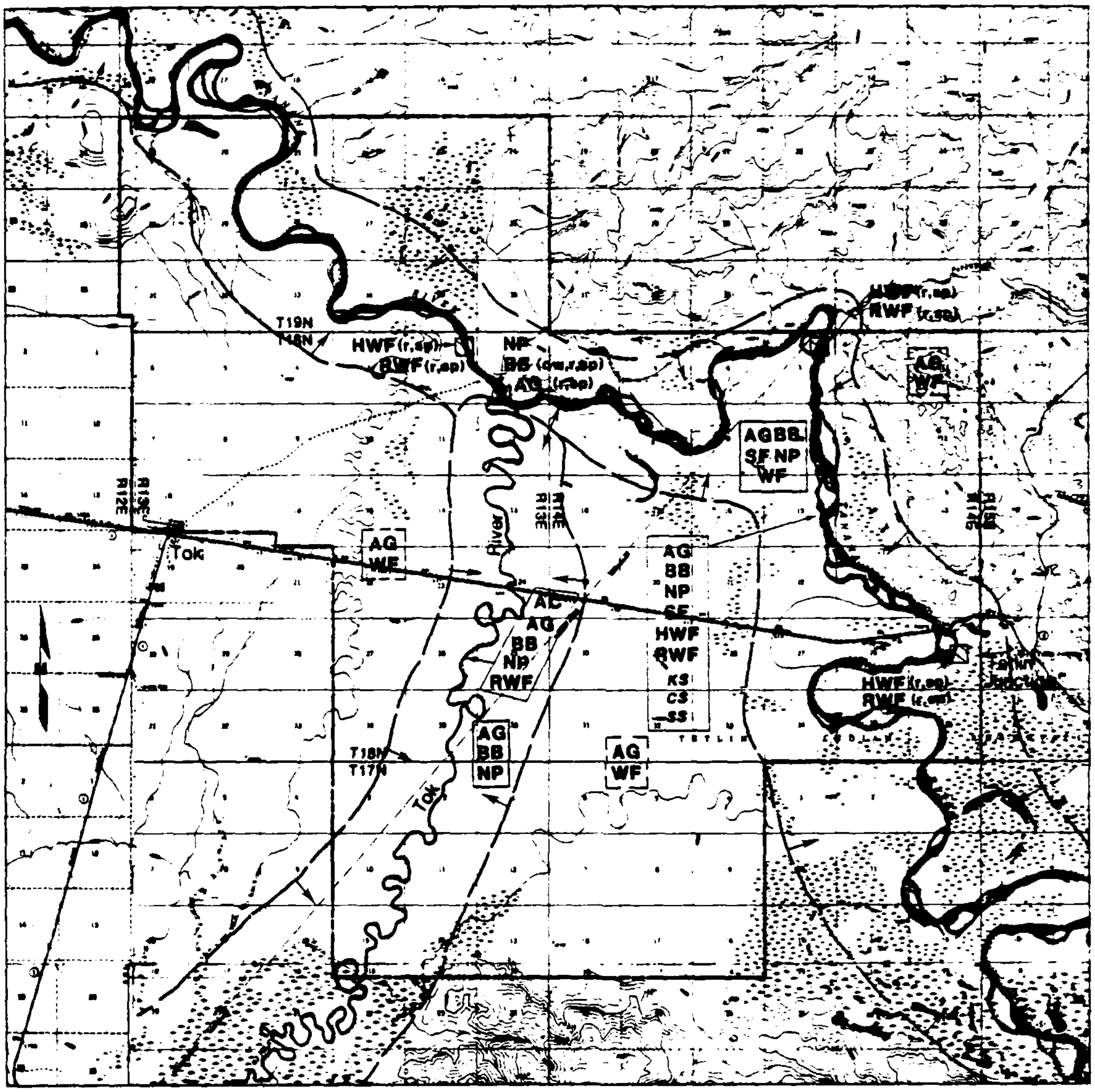
RT Species present

River corridor within which species may be present

LT Area outside corridor within which species may be present

Non-Anadromous Species		Anadromous Species	
AG	Arctic grayling	RS	Sockeye salmon
AC	Char		
RT	Rainbow trout		
LT	Lake trout		
BB	Burbot		

FIGURE 3-24 FISH DISTRIBUTION, PAXSON EAST STUDY AREA



Source: ADF&G, 1986b

Scale in Miles 0 2 4

Scale in Kilometers 0 5

SF NP	Species present
	River corridor within which species may be present
AG	Area outside corridor within which species may be present
(r, sp)	Specific site where species has been documented (r = rearing, sp = spawning, ow = overwintering)

Anadromous Species

- *KS* Chinook salmon
- *CS* Chum salmon
- *SS* Steelhead trout

Non-Anadromous Species

- **SF** Sheefish (Inconnu)
- **AG** Arctic grayling
- **NP** Northern pike
- **AC** Char
- **BB** Burbot
- **HWF** Humpback whitefish
- **RWF** Round whitefish
- **WF** Unspecified whitefish

FIGURE 3-25 FISH DISTRIBUTION, TOK STUDY AREA

stream resident from 1 to 4 years before out-migration.
In this area, steelhead spawn in the upper middle fork of the Gulkana below Dickey Lake (ADF&G, 1978), in the main stem of the Gulkana, and in Hungry Hollow. In the Tazlina River, steelhead spawn in the lower main stem and in 8-Mile Creek, Durham Creek, and Kaina Creek (Burger et al., 1983).

3.4.1.1.1.1 Glennallen Study Area

Sockeye salmon are found in the Tazlina River, Tolsona Creek, and Crosswind Lake, water bodies that lie partially within the Glennallen study area. Sockeye juveniles rear in Crosswind Lake. Chinook salmon occur in the Tazlina River as well as in Tolsona Creek, where adult chinook may spawn and juveniles rear. Steelhead spawn in the Tazlina River; whether spawning occurs in the small segment of the river encompassed by the study area is unknown. Coho salmon are present in the Gulkana and Tazlina River systems, but their distribution in the Glennallen study area per se is unknown (ADF&G, 1986c).

Sport fishing for sockeye salmon occurs in Tolsona Creek.

3.4.1.1.1.2 Gulkana Study Area

Chinook, sockeye, and coho salmon and steelhead trout are present in the Gulkana, Gakona, and Copper Rivers, all of which pass through the Gulkana study area. This species may also occur in Tolsona Creek, which passes through the eastern part of the study area. Chinook spawning occurs in the Gulkana River along the western boundary of the area. It is not known whether sockeye, coho, or steelhead spawn in the study area (ADF&G, 1986c).

An ADF&G sockeye salmon streamside incubation system operates in the upper Gulkana River. Sport fishing for sockeye salmon occurs in the Gakona, Gulkana, and Copper Rivers. The majority of salmon harvested from the Gulkana River are taken from powerboats in the Sourdough to West Fork confluence reach (Williams and Potterville, 1981). Chinook sport fishing occurs in the Copper and Gakona Rivers, and coho fishing occurs in the Copper. The extent to which individual species are harvested from the Gulkana study area is undocumented.

3.4.1.1.1.3 Indian Creek Study Area

Indian Creek, a tributary to the Copper River, supports coho, chinook, and sockeye salmon, as well as steelhead trout (ADF&G, 1986c). Steelhead, sockeye, and chinook salmon may spawn in Indian Creek, while juvenile chinook and sockeye rear there (ADF&G, 1986c). Indian Creek supports a sport fishery for chinook salmon.

3.4.1.1.2 Paxson East Study Area

Sockeye salmon is the only anadromous species present in the Paxson study area, but steelhead and chinook salmon are found nearby in the waters below Paxson Lake. The Gulkana Hatchery, the largest sockeye hatchery in the world, is located just outside the study area next to the Gulkana River and Summit Lake, 3 miles north of Paxson. This hatchery hatches 30 million sockeye per day, which are released in Summit Lake or several miles north in Gunn Creek. There is a proposal to build another hatchery on the Gulkana River 1 mile south of Paxson. There they would hatch 50-60 million sockeye and 2.5 million chinook salmon per year. Just north of the study area, Gunn Creek and Gunn Lakes are sensitive sockeye areas. Within the study area, an indigenous population of sockeye is found in Upper and Lower Fish Lakes and in Fish Creek. The fish are taken for sport, subsistence, and commercial purposes (ADF&G, 1986c; Roberson, 1986).

3.4.1.1.3 Tok Study Area

The Tok study area lies adjacent to the Tanana River, a major tributary of the Yukon River. The Yukon and Tanana Rivers are migratory pathways for salmon bound for spawning grounds in interior tributaries.

Chum salmon are the most abundant species of salmon in this watershed. They migrate from early July to September and spawn from mid-July through early November (Table 3-2). Fertilized eggs mature over the winter and hatch in February and March. Out-migration of fry occurs during high water runoff immediately following breakup (Buklis and Barton, 1984).

Chinook salmon, second in abundance in the Yukon drainage, are present in nearly all major tributaries of the Yukon, including the Tanana. Migrations occur from May through July (Table 3-2) with spawning occurring from July through September. Preferred spawning habitat is found in the mainstream of larger rivers, although smaller tributaries also are used. Incubation occurs throughout the winter, with hatching in late winter or early spring. Juvenile chinook salmon feed in the stream for 1 or more years before migrating out of the system in the spring.

Most of the coho spawning grounds in the Yukon basin occur in the upper Tanana River drainages (ADF&G, 1983). This species in-migrates from mid-July through November seeking spring-fed tributaries as preferred spawning grounds. Spawning occurs between September and January, with hatching and emergence the following spring. Juveniles generally remain in the stream environment for 1 year.

The only water body in the area surveyed for the presence of anadromous fish is the Tanana River (ADF&G, 1986b). Chum, coho, and chinook salmon are present throughout the study area, presumably migrating through the Tanana River enroute to spawning grounds elsewhere. No known sport fishery for salmon occurs in the area.

Table 3-2

GENERAL SALMON RUN TIMING IN THE MIDDLE YUKON RIVER AREA (TANANA RIVER), BY SPECIES

Salmon Species	Timing of Migration into Middle River	Timing of Spawning	Emergence from Gravel	Out-Migration
Summer chum	Early July to mid-Aug.	Mid-July to Aug.		
Fall chum	Mid-Aug. to late Sept.	Mid-Oct. to early Nov.	Early Apr. to early May	Apr. to mid-May
Chinook	Late June	Mid- to late Aug.		Ice breakup through July
Coho	Mid-Aug. to late Sept.	Late Sept. to late Nov.		

Source: Adapted from ADF&G (1986b).

3.4.1.2 Nonanadromous Fish

Many species of fish reside in streams and lakes of the Copper and Tanana River basins. However, this section addresses only those species that are important to the ecosystem, are used for subsistence purposes, or provide a sport fishery.

3.4.1.2.1 Copper River Basin

Nonanadromous fish present in all four study areas south of the Alaska Range include Arctic grayling, burbot, char, rainbow trout, and lake trout (ADF&G, 1986c).

Arctic grayling are the most abundant species of fish in interior Alaska. They are found in nearly all freshwater habitats in the region, but usually are more abundant in clear, cold streams and lakes (ADF&G, 1978). Spawning occurs between late April and early July, with most activity occurring between mid-May and mid-June (ADF&G, 1986a). Eggs are adhesive and sink to the stream bottom, where they are covered by materials dislodged during the spawning act.

Burbot are widely distributed and abundant in the larger rivers and at the confluences of tributaries. Mature fish spawn beneath the ice in gravel in streams or lake shallows during January and February. Hatching

occurs later in winter or in early spring. Burbot are generally sedentary but may make some seasonal movements.

Char are resident throughout the drainage basin. Spawning occurs from early July to early December; eggs incubate over the winter and fry emerge in the spring.

Rainbow trout are found in most clearwater tributaries of the Copper River, particularly the Gulkana River (ADF&G, 1978). Spawning occurs in streams during May and June. Fertilized eggs mature rapidly during spring and early summer, with hatching occurring 4 to 7 weeks after fertilization.

Lake trout are distributed throughout the high lakes of the Copper River drainage (ADF&G, 1978). Lake trout grow slowly and mature late; spawning occurs over coarse gravel and rubble in lakes, although some stream spawning has been noted (ADF&G, 1986c). Lake trout generally spawn in late summer or early fall, although considerable differences in time of spawning occur between populations in Alaska. Hatching occurs in March or April, depending on water temperatures. Lake trout may spawn again in later years and tend to return to previously used sites (Machniak, 1975; Martin and Olver, 1980).

The Glennallen Sport Fishing Area (SFA) encompasses the Glennallen, Gulkana, Indian Creek, and Paxson East study areas. Most angling pressure is along streams adjacent to the highway system (Williams and Potterville, 1983), although fly-in fisheries for rainbow and lake trout also occur in the region. In 1982, 60% of the lake trout harvest, 61% of the Arctic grayling harvest, and 83% of the burbot harvest in southcentral Alaska occurred in the Glennallen SFA.

3.4.1.2.1.1 Glennallen Study Area

Char are likely to occur in some lakes in the Glennallen study area, although their distribution is poorly known (ADF&G, 1978). Arctic grayling inhabit all major drainages and many lakes in the study area, with the largest populations found in moderately large, clearwater tributary streams. Moose Creek was stocked with Arctic grayling in 1983 (ADF&G, 1986d).

Crosswind Lake is an important habitat for nonanadromous fish, including lake trout, burbot, Arctic grayling, and rainbow trout. Other water bodies in the general vicinity may contain any or all of these species, along with char, although field surveys for them have not been conducted.

Arctic grayling are present in the Tolsona River, and rainbow trout and Arctic grayling are found in Tolsona Lake. Arctic grayling are present in Mud Lake, and rainbow trout are present in Round Lake. Both burbot and Arctic grayling occur in the Tazlina River and Twin Lakes, with Arctic grayling inhabiting the interconnecting stream and Moose Creek.

Sport fishing in the Glennallen study area includes fisheries for Arctic grayling in Tolsona Lake, Tolsona Creek, and Moose Creek, as well as burbot and rainbow trout fisheries in Tolsona Lake. The principal sport fishery in the area, however, occurs at Crosswind Lake, where Arctic grayling, burbot, and lake trout are taken, principally by fly-in fishermen. Angler days on Crosswind Lake have varied from 769 in 1981 to a high of 2,800 in 1978 (ADF&G, 1986c).

3.4.1.2.1.2 <u>Gulkana Study Area</u>

The Gulkana River is an important fish stream inhabited by lake trout, Arctic grayling, rainbow trout, and burbot (ADF&G, 1986c). Arctic grayling are very abundant in the Gulkana River.

The Copper River provides habitat for Arctic grayling and may be an important Arctic grayling overwintering area (ADF&G, 1986c); however, it is unknown whether that portion of the Copper River in the study area contains overwintering habitat. The Copper River also provides habitat for lake trout, burbot, and rainbow trout. Other water bodies in the study area support one or more of these species, along with char in some lakes. Tulsona Creek is known to be used by grayling and is within the range of char, burbot, and rainbow trout.

Sport fishing in this area occurs in the Gakona, Gulkana, and Copper Rivers, although the extent of fishing in each is not well known. Fisheries for Arctic grayling and burbot exist in the Gakona River. The Gulkana River is the most popular stream and supports the second most productive sport fishery for Arctic grayling in the state (Mills, 1982) along with a substantial fishery for rainbow trout. It is a popular float stream from Paxson Lake to Sourdough, where grayling are plentiful. Sport fishing for lake trout, burbot, rainbow trout, and Arctic grayling occurs in the Copper River (ADF&G, 1986c).

3.4.1.2.1.3 <u>Indian Creek Study Area</u>

Indian Creek provides habitat for char and Arctic grayling. A corridor extending approximately 1 mile west and 1 to 2 miles east of Indian Creek may contain rainbow trout, burbot, Arctic grayling, lake trout, and char. These species, with the exception of rainbow trout, may be found in appropriate habitats outside that corridor.

Sport fishing in the study area is limited to some angling for Arctic grayling in Indian Creek.

3.4.1.2.2 <u>Paxson East Study Area</u>

Burbot and lake trout are present in the Gulkana River, although only a small segment of it flows through the study area. Fish Creek, the principal tributary to the Gulkana in this area, provides habitat for burbot, and Arctic grayling are found in both Lower and Upper Fish Lakes. Although unsurveyed, other water bodies in the study area may

contain char, burbot, lake trout, rainbow trout, and Arctic grayling (ADF&G, 1986c).

Sport fishing in this study area includes fisheries for burbot, Arctic grayling, rainbow trout, and lake trout in the Gulkana River and for Arctic grayling and burbot in Fish Creek.

3.4.1.2.3 Tok Study Area

Several species of char, Arctic grayling, burbot, whitefish, and northern pike occur in the Tanana River Basin. Life history information on the first three species is presented in Section 3.4.1.2.1.

Three species of whitefish are known to inhabit the region: humpback whitefish, round whitefish, and inconnu or sheefish. Humpback whitefish are found in the Tanana River and its tributaries and are year-round residents of larger lakes. Spawning usually occurs in late September and October in gravel streams, and hatching probably occurs in late winter or spring. Some humpback whitefish are anadromous while others are resident (Alt, 1980), but migratory patterns are unknown for either form in this area of Alaska. Round whitefish also spawn in fall, and eggs hatch the following spring. This species has both lake and stream resident forms (Scott and Crossman, 1973). The inconnu, or sheefish, is a year-round resident in the upper Yukon River drainage basin (ADF&G, 1986b). Spawning occurs in the relatively swift main current of rivers during early October (Alt, 1975); hatching occurs late in the following winter or spring.

Northern pike, present throughout the Tanana River basin, prefer slow-moving waters of sloughs, lakes, and the lower reaches of larger rivers (ADF&G, 1986a). Pike spawn in the spring (mid-May), and the adhesive eggs hatch after 20 to 30 days.

The Fairbanks SFA includes the Tanana River basin. Arctic grayling are the most abundant species harvested, and the Fairbanks SFA is the largest grayling fishery in the state (Mills, 1982). However, large sport harvests of northern pike, burbot, whitefish, and lake trout also occur in the Fairbanks SFA.

The Tanana and Tok Rivers provide the principal habitats for nonanadromous fish in this study area (ADF&G, 1986b). Burbot, Arctic grayling, and northern pike are found in both rivers; char occur in the Tok River; and humpback whitefish, round whitefish, and sheefish occur in the Tanana River. Burbot inhabit the Tanana River near Tok during spring, fall, and winter (Chihuly et al., 1980). Native populations of northern pike probably are present in lakes located at elevations lower than 2,000 ft and connected to a river system; landlocked lakes are usually barren of pike (Peckham, 1983).

Just below the confluence of the Tok and the Tanana Rivers, spawning and juvenile rearing habitat for humpback and round whitefish

has been documented. At the confluence of the Tok, burbot are known to over-winter, spawn, and rear as juveniles; Arctic grayling and northern pike also spawn and rear at this site; and spawning of northern pike has been documented. Humpback and round whitefish spawn and juveniles rear at two additional sites on the Tanana River: just above the USGS gage, and near the sharp bend in the northeastern sector of the study area.

Water bodies in a corridor extending approximately 1 mile on either side of the Tanana and Tok Rivers may also contain fish characteristic of each river.

In the Tok River corridor, burbot, Arctic grayling, and northern pike may be present. In the Tanana River corridor, burbot, Arctic grayling, northern pike, sheefish, and whitefish may occur. Arctic grayling or whitefish may be found in water bodies outside these corridors.

Sport fishing occurs for burbot in the Tanana River from approximately 4 miles below to 4 miles above the USGS gage. The sport fishery for burbot, Arctic grayling, and northern pike is fairly small and is undertaken primarily by local residents.

3.4.1.3 Other Aquatic Biology

Large numbers of ponds and lakes in this region are the result of the last glacial ice sheet, which melted in place less than 11,000 years ago (Pewe and Reger, 1983). Most of these ponds cover less than 2.5 acres and are subject to fluctuating water levels. Ice cover generally forms on the lakes and streams by mid-October, and spring breakup typically occurs during the second week in June (Barsdate and Alexander, 1971).

Most lakes contain high concentrations of dissolved oxygen at all depths and rarely, if ever, become anoxic (Koenings and McDaniel, 1983; LaPerriere and Casper, 1976). Calcium and bicarbonate are the most abundant ions in the waters of this region. Alkalinities typically range from 20 to 40 ppm, and pH values are usually circumneutral (6.8 to 9.5). Most waters are highly colored and low in aquatic productivity.

The only information available on phytoplankton community structure comes from Van Whye and Peck (1968) for Paxson and Summit lakes, in which Asterionella and Ulothrix dominated. The blue-green Microcystis was abundant in Summit Lake by late July. Other genera observed included the dinoflagellate Ceratium, the chrysophyte Dinobryon, and the green alga Actinastrum, as well as the blue-green algae Anabaena, Aphanizomenon, and Coelosphaerium.

Some aquatic vascular plants provide essential minerals to moose in spring as well as a very important source of food and physical habitat for waterfowl.

No data on the density or community structure of the benthic algae communities inhabiting the lakes of this region are available, but they are probably dominated by pennate diatoms. Wojcik (1954) reported that the calanoid copepod, Diaptomus, was the dominant zooplankton in the Tangle Lakes. Van Whye and Peck (1968) reported Copepoda, Nauplias larvae, Polyarthra, Kellicottia, and Keratella in Paxson Lake; Keratella, Kellicottia, Copepoda, and Nauplias larvae were reported in Summit Lake.

No data are available on the benthic communities of lakes in this region, but they are probably dominated by the chironomids. Wojcik (1954) described the benthic community of the Tangle Lakes as consisting of annelid worms, nematodes, Chironomus, Gammarus, pea clams, and snails.

Limnological information about the streams draining this region is limited to brief surveys conducted along the Gulkana River, which drains Summit and Paxson Lakes (Albin, 1977; Nauman and Kernodle, 1974, 1977). The invertebrate community was dominated by chironomid larvae, followed by plecopterans, trichopterans, and ephemeropterans. Studies on spring-fed streams, conducted in the nearby Susitna River drainage well before breakup in early April, revealed very high benthic algal standing crops that supported high chironomid densities (Van Nieuwenhuyse, 1985). At this time of year, many salmonids emerge from redds and begin feeding. The productivity of springs is probably important to natural fish production in the Copper and Tanana River drainages as well.

Several spring-fed streams occur along certain reaches of the Gulkana and Gakona Rivers and the southern bank of the Tanana River. Fisheries of the latter are described by Bendock (1974).

3.4.2 Birds

Few quantitative data have been compiled on the birds of the northern boreal forest in Alaska. Available references include those on populations and energetics in two upland forest communities compiled by West and DeWolfe (1974); information on population density and diversity as well as on habitat selection gathered by Spindler (1976) for each of five types of lowland forest community; species composition, abundance, and distribution data collected by Theberge (1976) near Kluane Lake, Yukon Territory; and detailed information on avian community structure, habitat occupancy levels, and species use patterns gathered by Spindler and Kessel (1980) in the upper Tanana River valley of Alaska. Additionally, Erskine (1977) provides information from the boreal forest of Canada, some of which is relevant to Alaska conditions.

Collectively, these studies describe a fairly simple breeding avifauna, whose members often exhibit greater adaptability in their uses of habitat than is common in more temperate regions of North America. For example, a species that breeds only in a well-defined ecotype (such as grassland) in lower latitudes often breeds successfully in a broad variety of habitat types in higher latitudes. This difference reflects partly the northern boreal forest's relative simplicity of structure and form, as well as the generally low productivity of the land.

From standardized aerial transect surveys flown in the study region for more than 30 years, the U.S. Fish and Wildlife Service has been compiling numerical data on breeding waterfowl pairs. Ten such transects cover the Nelchina Plateau from the eastern foothills of the Talkeetna Mountains to the vicinity of the Indian Creek study area; two other transects cover the upper Tanana valley immediately southeast of Tok.

With few exceptions, aerial survey data such as these can be used only for cautious trend analyses.

About 166 species of birds have been recorded in and adjacent to the study region (Gabrielson and Lincoln, 1959; Kessel and Gibson, 1978; Yocum, 1963; Sage, 1975). About half of all species present are water birds, a situation common in Alaska.

3.4.2.1 Raptors

Thirteen species of raptors occur in the region, but little is known of any of them. The goshawk is primarily a bird of Alaska's great interior valleys and occurs throughout the region as a year-round resident (Gabrielson and Lincoln, 1959). Nesting may occur in all of the major forest associations within the region; when available, however, birch appears to be the nest tree of choice (McGowan, 1975). Eggs hatch typically from late May through early June, and the young remain in the nest for about 39 days (McGowan, 1975). This time frame generally applies to all the other raptors breeding in the region.

Sharp-shinned hawks breed within the region, and they appear to nest preferentially in thick growths of white spruce (Gabrielson and Lincoln, 1959; Spindler and Kessel, 1980). No further substantive information exists for this species in this area of Alaska.

Red-tailed hawks appear to be fairly common breeders in the study region (Gabrielson and Lincoln, 1959; Yocum, 1963), but nothing is known of their breeding density. The species prefers the tallest trees for nesting.

Swainson's hawk also occurs within the area of interest (Yocum, 1963) and may well breed there. It is a bird of open country and appears to reuse nest platforms, a common habit of many raptor species (Gabrielson and Lincoln, 1959).

Rough-legged hawks are known breeders of the study region (Gabrielson and Lincoln, 1959), and they occur in both forested regions (where they nest in the tops of tall trees) and alpine areas (where ledges provide a nesting substrate). It is the biggest, slowest, and most commonly seen hawk of interior Alaska (Gabrielson and Lincoln, 1959). Nothing is known of this species' regional abundance.

Golden eagles, the largest native eagle species of North America, are widespread and relatively common breeders in interior Alaska

(Gabrielson and Lincoln, 1959; Sage, 1975). They inhabit primarily alpine regions, where they nest on ledges, but they also occur much less commonly in dense timber, where they nest in the tops of the tallest trees (Gabrielson and Lincoln, 1959).

Bald eagles are conspicuous breeding birds of the study region (Gabrielson and Lincoln, 1959; Yocum, 1963; Sage, 1975). Detailed data on their average numbers are generally lacking; however, 20 active nests occur in the Tanana valley portion of the Tetlin National Wildlife Refuge (U.S. Fish and Wildlife Service, 1985a), about 25 miles southeast of Tok. Bald eagles usually nest in the tops of large trees but also use rock ledges. They generally eat fish, and their nests are always located within view of productive water bodies.

Marsh hawks are present within the study region (Sage, 1975); however, it is unclear from available information whether any breed there.

Ospreys are a relatively common member of the breeding fauna of the upper Tanana valley, where an estimated 20 pairs (roughly 10% of the total estimated number in all of Alaska) breed on the Tetlin National Wildlife Refuge (U.S. Fish and Wildlife Service, 1985a).

Gyrfalcons breed above tree line in alpine environments of the study region; nothing is known of their numbers.

The anatum race of the peregrine falcon has long been known to breed in the middle reaches of the Tanana River, and it occurs in both that valley and the Copper River valley as a migrant (Gabrielson and Lincoln, 1959). No nests are known in any of the study areas.

Kestrels and merlins also breed in the study region (Gabrielson and Lincoln, 1959; Sage, 1975) but apparently in low numbers.

3.4.2.2 Waterfowl

Based on review of more than 25 years of trend data compiled by the U.S. Fish and Wildlife Service, and on information from James King, U.S. Fish and Wildlife Service flyway biologist, Evans and Cuccarese (1977) rated the majority of the Nelchina Plateau as being low-density duck breeding habitat (fewer than 25 nesting ducks per square mile). A small area east and south of Crosswind Lake, however, supports nesting densities of ducks that are, on average, slightly more than 25 ducks per square mile; this area was rated medium. Principal breeding species of the Nelchina Plateau are widgeon, mallard, pintail, and lesser scaup (Bellrose, 1976).

The Tetlin National Wildlife Refuge supports an average of about 40,000 breeding ducks (U.S. Fish and Wildlife Service, 1985a) most of which nest in and immediately adjacent to the flood plain of the upper

Tanana River. Evans and Cuccarese (1977) rated this area as high-density nesting habitat. Principal breeding species here are lesser scaup, white-winged scooter, green-winged teal, widgeon, mallard, and ring-necked duck.

Few geese nest in the study region; Evans and Cuccarese (1977) rated goose habitat density on both the Nelchina Plateau and in the upper Tanana valley as low (fewer than 9 nesting geese per square mile).

Evans and Cuccarese (1977) rated the Nelchina Plateau as being "high-density" trumpeter swan breeding habitat (0.1 to 0.9 nesting swans per square mile); as many as 600 individual swans have nested in the area (Hansen et al., 1971). In the intervening years, the Alaska trumpeter swan population has grown dramatically; today, about 2,000 birds nest on the Nelchina Plateau (U.S. Fish and Wildlife Service, 1985b). The total Alaska population of trumpeter swans is between 8,000 and 10,000, and the Nelchina Plateau now should be categorized as a "key area" under Evans and Cuccarese's (1977) habitat rating scale (1 or more nesting swans per square mile).

Few trumpeter swans currently breed in the upper Tanana River valley; today, six pairs nest on the whole of the Tetlin National Wildlife Refuge (U.S. Fish and Wildlife Service, 1985a). This may change, however, if the Alaska swan population continues the dramatic growth seen over the past 15 years.

High mortality losses of flightless young swans result chiefly from predators (primarily bears and wolverines) and desertion; breeding trumpeter swans are notoriously sensitive to human activity during their nesting phase (Banks, 1960; Hansen et al., 1971). On average, each trumpeter swan pair successfully rears one of its young to the flight stage; thus, annual production in the region may average approximately 1,000 swans.

3.4.2.3 Other Birds

Using Kessel's (1979) bird habitat classification system as a guide, 13 breeding bird habitats could occur in the region: low and medium shrub thickets; tall shrub thickets; deciduous forest; mixed deciduous-coniferous forest; coniferous forest; scattered woodland and dwarf forest; lacustrine waters and shorelines; fluviatile waters and shorelines; cliffs and block fields; wet meadow; grass meadow; tall forb meadow; and dwarf shrub meadow. In their study of birds of the Tanana River valley, Spindler and Kessel (1980) found 19 species breeding in low and medium shrub thicket habitat. Two sparrows, Lincoln's and white-crowned, were the chief breeders in these types.

The tall shrub thicket habitat supported the greatest diversity and density of breeding birds in the Tanana River valley. Spindler and Kessel (1980) recorded 18 breeding species; the most abundant were yellow warbler, orange-crowned warbler, and alder flycatcher.

Spindler and Kessel (1980) judged deciduous forest habitats to be of intermediate importance to breeding birds in the Tanana River valley in terms of both densities and species. Mixed deciduous-coniferous forest habitat supported the largest number of avian species and the greatest density and biomass of breeding birds in upper Tanana River valley forests. Coniferous forest habitat had the lowest occupancy level of all habitats sampled in the upper Tanana valley.

In Spindler and Kessel's (1980) Tanana River valley study, scattered woodland and dwarf forest habitats were represented by two distinct vegetation types: a white spruce-birch association and a black-spruce bog type. No specific information on avian use of wet meadow, cliffs and block fields, lacustrine waters and shorelines, fluviatile waters and shorelines, grass meadow, tall forb meadow, and dwarf shrub meadow habitats exists for the region of interest. Cliffs and block fields in the region, however, certainly afford breeding habitat for species such as cliff swallows; lacustrine and fluviatile habitats are suitable for species such as dippers, terns, and sandpipers; and alpine habitats provide food and cover for such species as ptarmigan, golden plover, greater yellowlegs, horned lark, and shrike.

3.4.2.4 Migratory Patterns

The Copper and Tanana River valleys are two of Alaska's most important migration corridors for birds (Gabrielson and Lincoln, 1959). Respectively, they serve populations of the Pacific and Central flyways.

In spring, birds using the Copper River valley generally follow the coast from points south until reaching the Copper River delta, a migratory stop of great importance on the Gulf of Alaska. From there, the birds turn north and follow the Copper River through the Chugach Range to reach the Nelchina Basin. Movements from this point northward are not well documented, but the migration front may continue due north, crossing the Alaska Range through Isabel Pass. Alternatively, it may proceed northeastward until it intercepts the Tanana River valley.

Birds also approach the Tanana River valley in spring directly from the south and east by following the eastern flank of the Rocky Mountains north through Canada. Although available quantitative data are limited chiefly to sandhill crane movements, birds appear to enter the Tanana valley from Canada through a fairly narrow migration corridor that is roughly centered on the Tok study area.

The fall migration is generally a reversal of that seen in spring. However, Kessel (1984) found that sandhill cranes migrating in the fall left the Tanana valley for Canada in a less constricted corridor than that used in spring.

Some estimates exist of the numbers of waterfowl using these two migration corridors. Generally, they are rough estimates based on information on long-term breeding pairs, average species-specific

recruitment data, and the professional judgment of U.S. Fish and Wildlife Service flyway biologists. A summary of these estimates is provided in Bellrose (1976).

More substantive data are available for whistling swans, trumpeter swans, and sandhill cranes. An overview of the estimated use of each of the two migration corridors by ducks, geese, swans, and sandhill cranes is provided in Table 3-3. These tables are provisional because of the nature of the available data and should be used chiefly as general indicators of bird use. Roughly 2,000 whistling swans use valley habitats of the Tanana River in the Tetlin National Wildlife Refuge for migration staging (U.S. Fish and Wildlife Service, 1985a). Most of the sandhill crane population using the Tanana River migration corridor also uses resting habitats throughout the valley.

3.4.2.5 Glennallen Study Area

The Glennallen study area includes an area of relatively good duck breeding habitat, which, from a continental perspective, is of medium quality (Figure 3-26). It is the most productive duck breeding habitat on the Nelchina Plateau (Evans and Cuccarese, 1977), an area bounded by the Talkeetnas on the west, the Wrangells on the east, the Alaska Range on the north, and the Glenn Highway on the south.

The Glennallen study area includes one of the principal breeding grounds of trumpeter swans in North America and is heavily used for this purpose. The Nelchina Plateau as a whole supports roughly one in five of the world's breeding trumpeter swans. It is also an important migration stop for members of this species breeding farther north in tributary basins of the Yukon River. The total of breeding and migratory birds indicates that, at times, roughly one of every three trumpeter swans in existence is present in the vicinity of the Glennallen study area.

Figure 3-27 shows trumpeter swan flocks and nesting areas observed in the vicinity of the Glennallen study area. This figure also shows circles around broods to indicate the U.S. Fish and Wildlife Service policy of maintaining a 1-mile buffer zone of restricted human activity. On federal land, the Fish and Wildlife Service restricts low-level aircraft flights and motorized-vehicle use in these buffer zones. Although the State of Alaska does not have a particular policy regarding this matter, it also discourages human disturbance of trumpeter swan broods on state and private land.

Table 3-3

COPPER AND UPPER TANANA RIVER VALLEY WATERFOWL MIGRATION

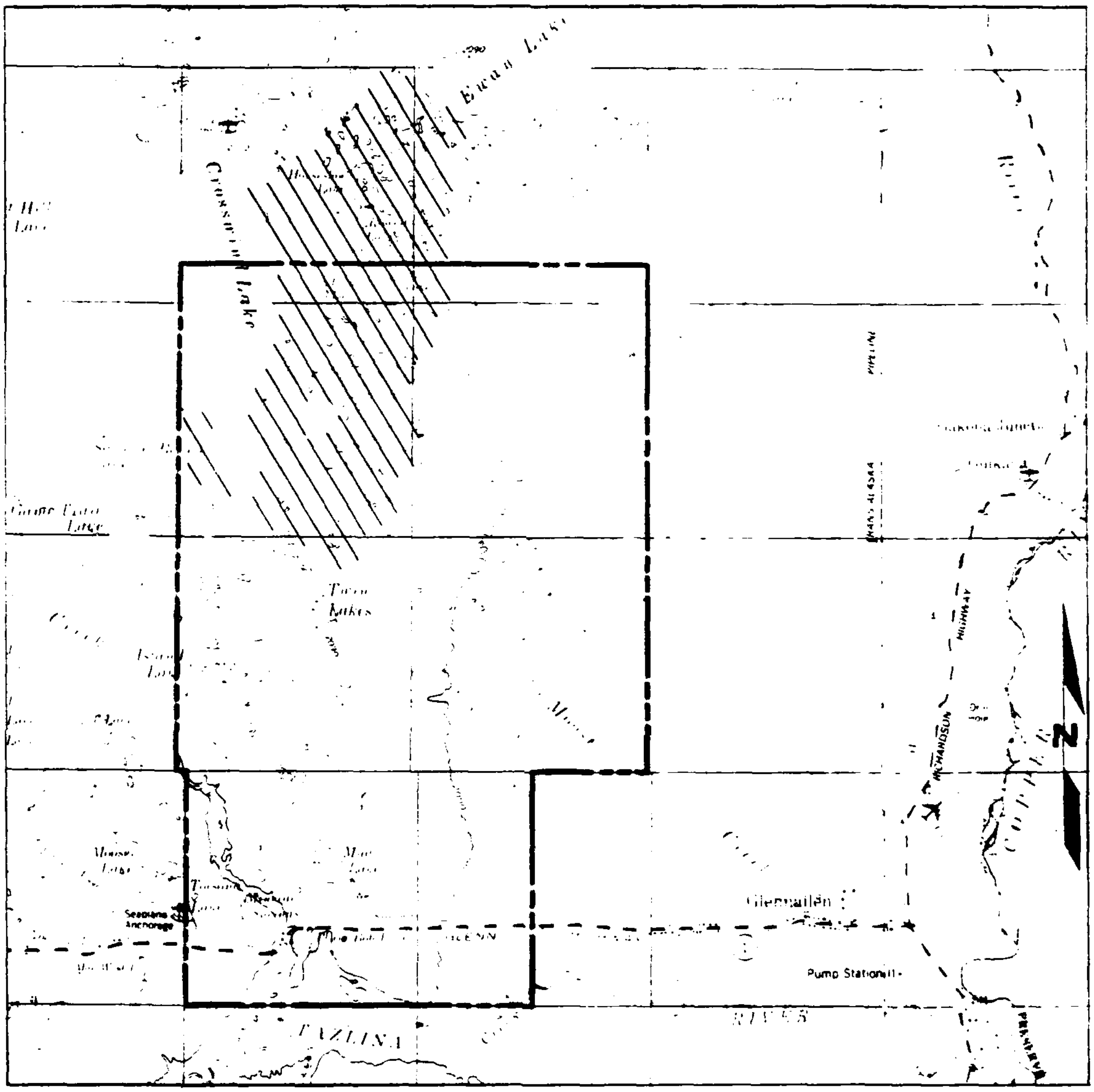
Species	Number[a]	
	Copper River[b]	Upper Tanana River
Trumpeter swan[c]	4,000 - 5,000	18
Whistling swan[c]		2,000 +
White-fronted goose		25,000 to 50,000
Lesser snow goose		10,000 to 50,000
Canada goose		15,000 to 50,000
Widgeon	100,000	100,000
Green-winged teal		65,000 to 150,000
Mallard		100,000
Pintail		50,000 to 75,000
Shoveler		2,000 to 15,000
Canvasback		8,000 to 20,000
Greater scaup		75,000 to 150,000
Lesser scaup	75,000 - 250,000	30,000 to 75,000
Sandhill crane		150,000 to 200,000

Sources: Bellrose, 1976; U.S. Fish and Wildlife Service, 1985a; and Kessel, 1984.

[a]Ranges given reflect partly the imprecision of the data and partly year-to-year variations in population size.

[b]A blank space indicates that use by the particular species is very low or nonexistent.

[c]Swan numbers from spring surveys have been adjusted by applying long-term average recruitment data.



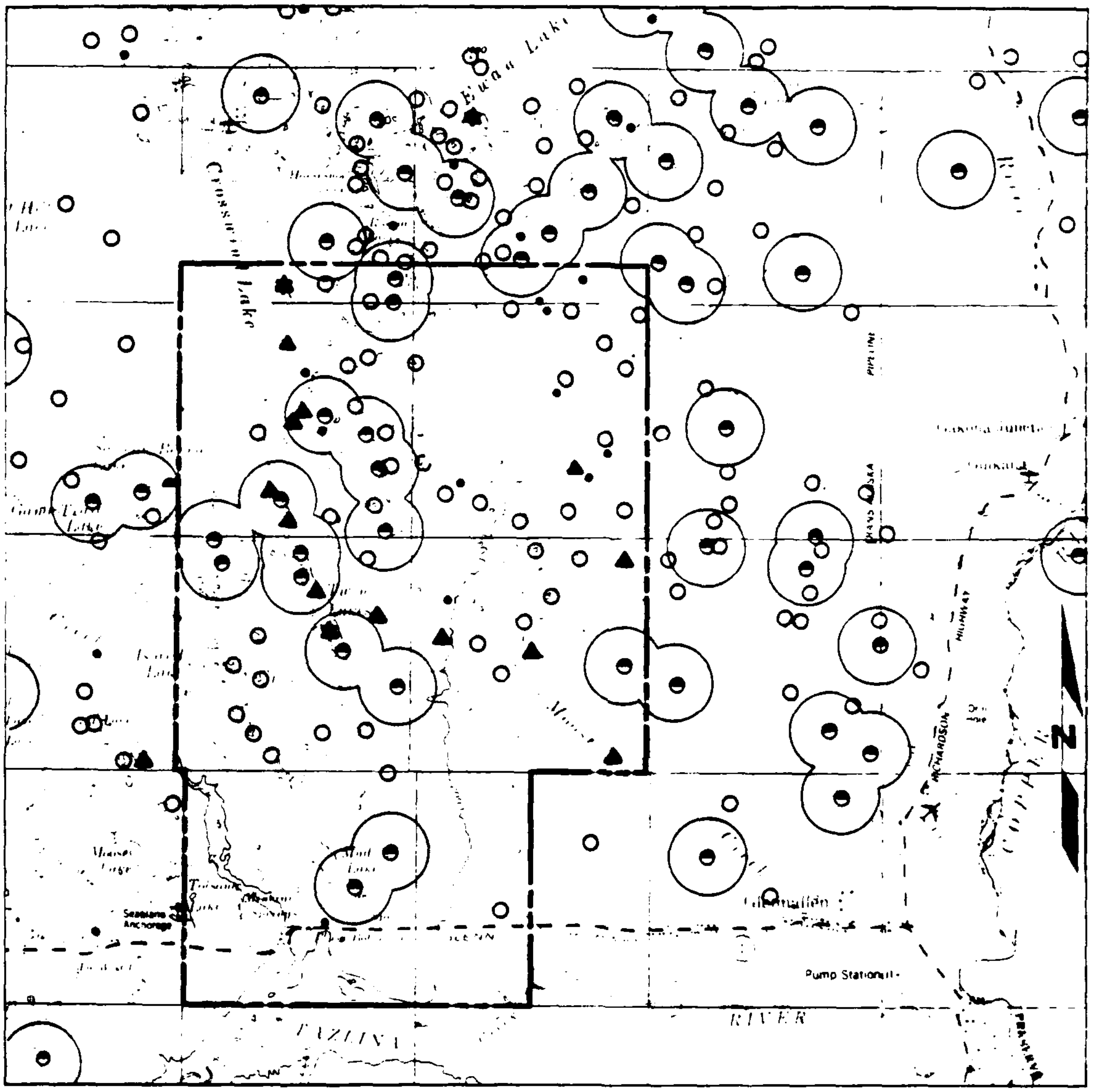
Source: Evans and Cuccarese, 1977

0 5
Scale in Miles

0 5 10
Scale in Kilometers

Duck Breeding Habitat

FIGURE 3-26 GENERAL DISTRIBUTION OF MEDIUM DENSITY DUCK BREEDING HABITAT, GLENNALLEN STUDY AREA



Source: USF&WS, 1985b

0 5
Scale in Miles

0 5 10
Scale in Kilometers

Sighting Location and Type

- • Single Adult
- ○ Breeding Pair
- ◒ Brood
- ▲ Flock (9 or Less)
- ✸ Flock (10 or More)
- ◯ Buffer Zone around Brood: Radius of 1 Mile

FIGURE 3-27 TRUMPETER SWAN NESTING AREAS, GLENNALLEN STUDY AREA

3.4.2.6 Gulkana Study Area

This study area also affords nesting habitat for trumpeter swans. Although brood densities are lower than those of the Glennallen study area (Figure 3-28), a trumpeter swan brood was sighted within the Gulkana study area in 1985. Duck breeding densities are quite low (Evans and Cuccarese, 1977).

3.4.2.7 Indian Creek Study Area

No notable concentrations of birds are known to occur in this study area. During winter, however, it is possible that large flocks of ptarmigan are present.

3.4.2.8 Paxson East Study Area

No major concentrations of birds are known to occur in this study area, but, as with Indian Creek, large numbers of ptarmigan may be present seasonally.

3.4.2.9 Tok Study Area

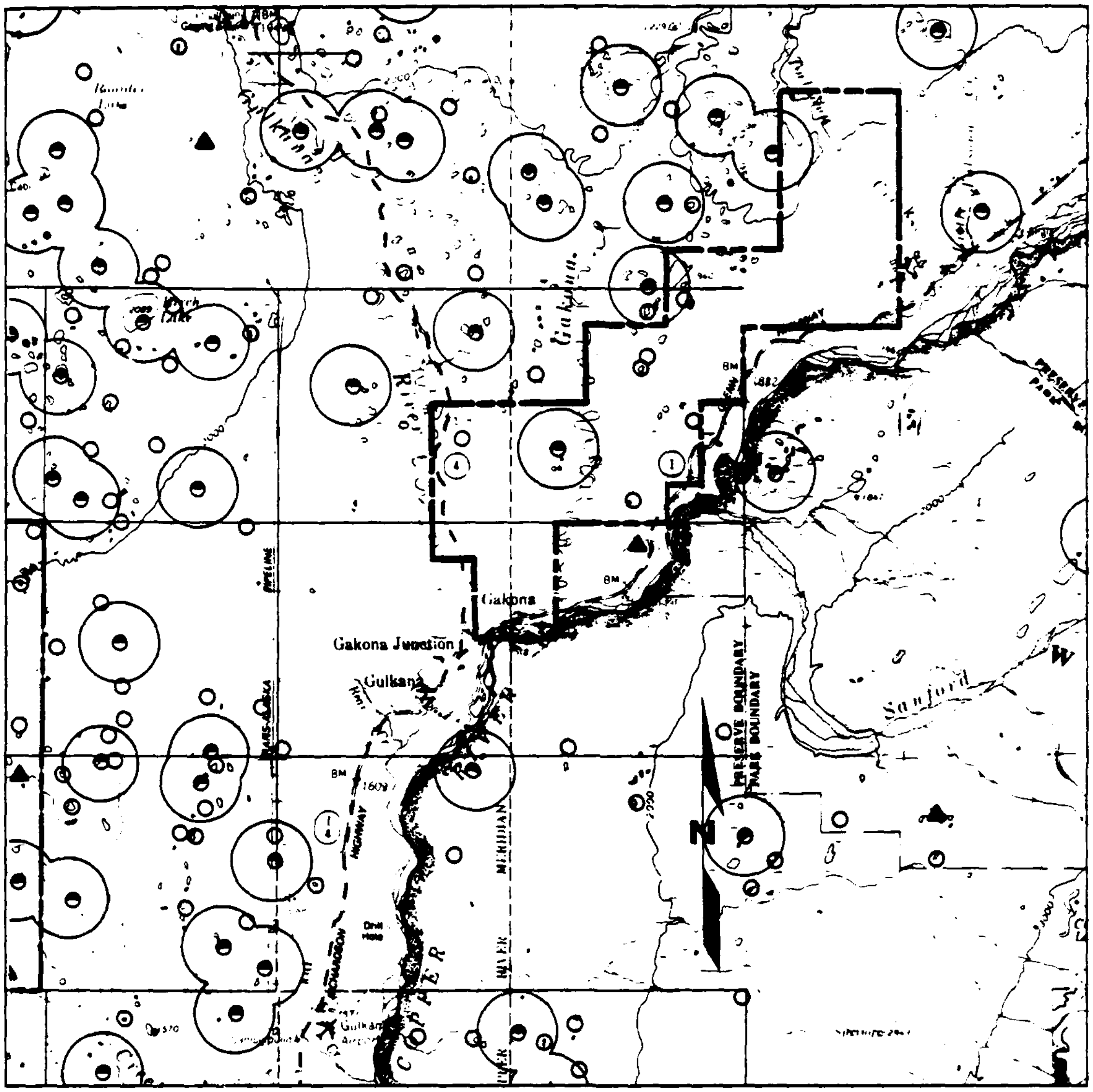
The Tok study area centers on one of the principal points of entry used by birds migrating into and out of Alaska. During periods of inclement weather, which impedes migration, it is likely that very large numbers of ducks, geese, sandhill cranes, raptors, songbirds, and perhaps whistling swans rest in the area.

Trumpeter swans may breed within, or in the general vicinity of, the Tok study area, but density of use is expected to be low. Bald eagles are common nesting birds in the upper Tanana River valley and it is possible that some breed in the Tok study area. Ospreys are also common nesters in the upper Tanana valley; roughly 10% of Alaska's total population of this species nests to the south of the Tok study area in the Tetlin National Wildlife Refuge.

3.4.3 Mammals

Alaska's southcentral region and the upper Tanana valley portion of the Alaska interior encompass a variety of mammalian habitats. These habitats may be broadly categorized by their biophysical features as aquatic, wet/moist tundra, forested lowland, riverine, and alpine/upland types.

Habitat values vary in importance from low to prime (Alaska Department of National Resources, 1986). "Prime" habitats, such as the Lake Louise Plateau (Glennallen study area) support maximum game animal densities and are essential to population maintenance. "Important" habitats support medium to high mammal densities and generally cover vast expanses; their cumulative value is significant to population maintenance. "Low value" habitats are less necessary for maintaining



Source: USF&WS, 1985b

0 5 Scale in Miles

0 5 10 Scale in Kilometers

Sighting Location and Type

- Single Adult
- Breeding Pair
- Brood
- Flock (9 or Less)
- Flock (10 or More)
- Buffer Zone around Brood: Radius of 1 Mile

FIGURE 3-28 TRUMPETER SWAN NESTING AREAS, GULKANA STUDY AREA

the existing distribution, abundance, and productivity of a species within a given area.

Habitats within and peripheral to the study areas collectively support approximately 43 mammal species. Large mammals common to all study areas are caribou, moose, and black and brown bears. Additionally, Dall sheep range in the vicinity of the Paxson East study area. Smaller mammals are generally abundant throughout all study areas. Common furbearers include marten, lynx, mink, weasel, otter, beaver, muskrat, fox, coyote, gray wolf, and wolverine (ADF&G, 1986b). Snowshoe hares, squirrels, and marmots occur in abundance in most study areas and, together with microtine species, figure prominently in the ecology of carnivorous mammals (Stephenson, 1984). Distributions and life histories of these species are summarized in Hall (1981).

3.4.3.1 Big Game

A combination of open lowland, upland, and forested terrain in the Copper-Tanana River lowlands provides prime to low-value habitat for big-game species. Caribou and moose are particularly conspicuous during the winter season, when animals concentrate in preferred range areas near parts of the Glenn and Richardson Highways. Black bears are more common than brown bears, except for the Paxson East study area, where grizzly bears reportedly occur in high numbers (Hemming and Morehouse, 1976). The nearest significant population of Dall sheep is located about 10 miles north of the Paxson East study area.

The Nelchina and Fortymile caribou herds, 2 of the 22 major herds in Alaska, are important to subsistence and sport hunters because of their relative abundance and accessibility from population centers. The Mentasta and Chisana caribou herds, two minor herds, also occur in the region.

The Nelchina herd occupies about 20,000 mi^2 of land bounded by four mountain ranges: the Alaska range to the north, the Wrangell Mountains to the east, the Chugach Mountains to the south, and the Talkeetna Mountains to the west (Hemming, 1971). This herd has used numerous winter ranges during the past 30 years, located from the Nenana-Yanert Fork drainages to the Talkeetna River, and east to the Mentasta and Wrangell mountains (Skoog, 1968; Hemming, 1971). During the spring migration period, Nelchina caribou travel west across the Lake Louise Flat from the Crosswind Lake area en route to their principal calving grounds in the eastern Talkeetna Mountains (Pitcher, 1982). The female-calf segment of the population spends the summer along the northern and eastern slopes of the Talkeetna Mountains. Males summer in widespread locations throughout upland habitats of the Nelchina Basin (Skoog, 1968). The animals disperse and the sexes begin to intermingle in late summer as they move from the mountains onto the western part of the Lake Louise Flat and the Alphabet Hills in anticipation of winter (Pitcher, 1982).

A Nelchina caribou census conducted in June 1981 revealed 19,264 caribou, with 10,416 females, 3,035 males, and 5,813 calves (Pitcher, 1982). Over a 10-year period (1972-82), the annual hunter harvest averaged 670 animals (Pitcher, 1982). Except for the Tok study area, the Nelchina caribou herd ranges over all study areas and, because of its socioeconomic value, constitutes the most important mammal group.

The Fortymile caribou herd formerly ranged in a 35,000-mi^2 area between the White Mountains, the southwest Yukon Territory, the Yukon Flats, and the Tanana River (Hemming, 1971). The present range is only a fraction of that because of reduced herd size. Neither the present nor the former range of the Fortymile caribou herd includes any of the study areas.

According to Skoog (1968), the small Mentasta and Chisana herds are remnants of the Fortymile herd that ranged in the Mentasta Mountains and the Nabesna-White River country, respectively, until the early 1930s. Small bands of these caribou reportedly have wintered in the Northway-Tetlin Flats area (near the Tok study area) during recent winters (Tobey, 1986).

Moose are widely distributed as transitory subpopulations throughout each of the study areas (ADF&G, 1973). Density varies by season and by habitat within each study area. Moose are sparse in the alpine habitat of the Paxson East study area, compared with a relatively higher density in the Copper and Tanana River lowlands.

Winter range is a key feature in the maintenance of moose populations. Winter range consists of two basic types: early shrub successional stage and climax vegetation. Habitat in shrub successional stages generally makes the best winter environment. Large portions of the study areas consist of climax vegetation of low value to moose. Bottomlands subjected to flooding, ice scour, and erosion, as well as areas altered by man-made clearings (e.g., road, power line, and pipeline rights-of-way) produce seral vegetation that can support relatively large numbers of moose. This condition occurs within and immediately adjacent to the study areas.

Black bears and brown bears are present in the study areas, the former species being more common. Species density varies with physiographic features of the Copper and Tanana lowlands and the Alaska Range regions. Extensive open plateau and moist tundra habitats apparently afford marginal conditions compared with elevated places or broad valley bottoms such as occur in the Copper and Tanana drainages. Like moose, many bears are members of transitory subpopulations.

Black bears characteristically prefer semi-open forest areas year-round. Favorite springtime haunts include river bottoms, lakeshores, and marshy lowlands, while in summer and fall bears move to higher elevations in search of new berry crops. Although little is known about black bear denning in interior Alaska, the species appears to prefer better-drained sites near subalpine and forested areas (ADF&G, 1973).

Although brown bears are seasonally common in open and heavily timbered lowlands, alpine and subalpine habitats are more frequently used. Intensive use of lowland drainage systems occurs when migratory fish are present and during early spring, when bears emerge from winter dens. Brown bears concentrate on streams such as Fish Creek and the Gulkana River during summer and fall salmon runs. They den in alpine zones from mid-October through early May (ADF&G, 1973).

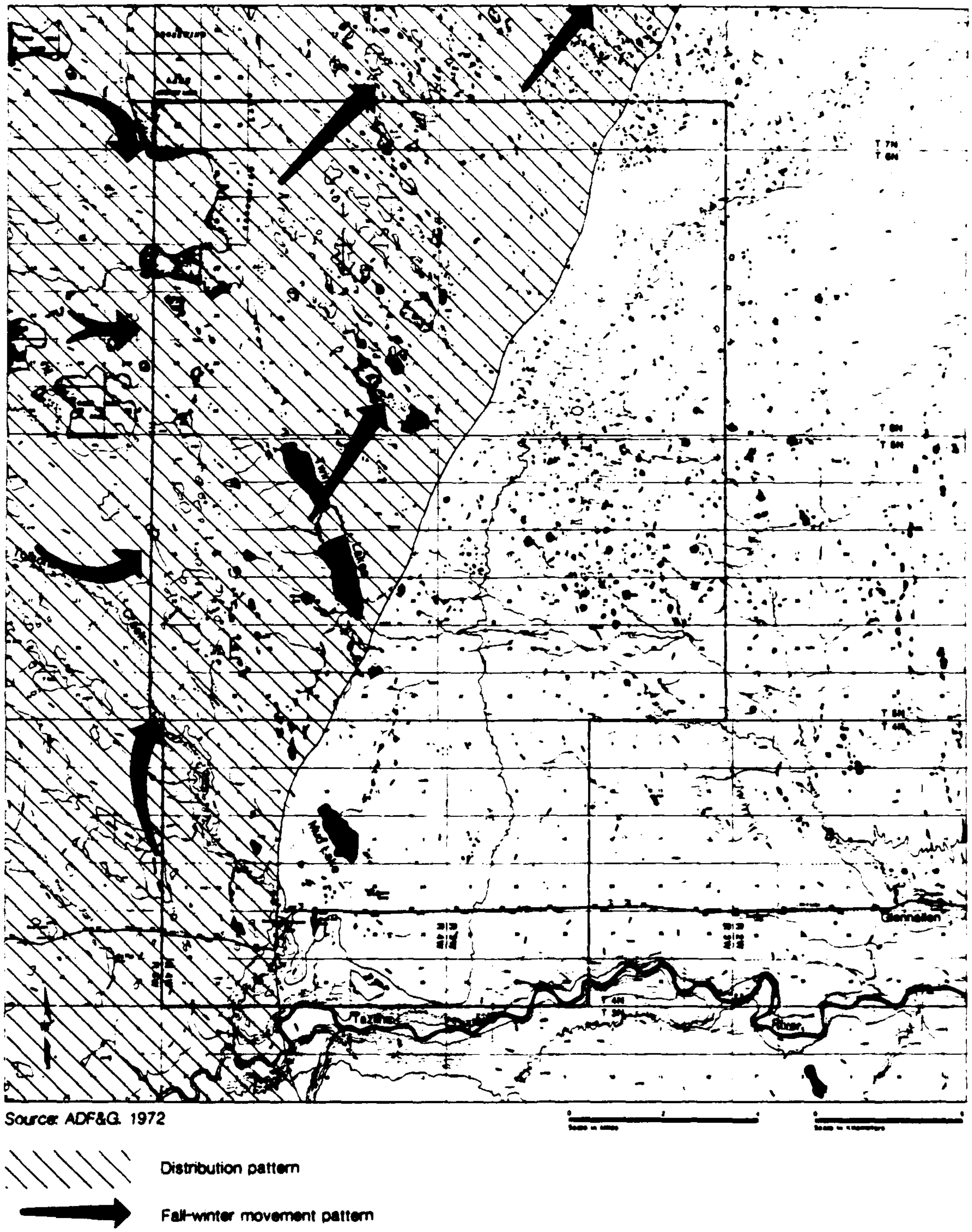
As with the other big-game animals, good road access and the ability of hunters to cover remote areas in the southcentral and interior parts of Alaska enable the harvest of both bear species. No standard surveys of black and brown bears ranging in the Lake Louise plateau, the Gulkana and Tanana River valleys, or the Indian Creek area have been conducted by the Alaska Department of Fish & Game (ADF&G, 1984). General observations and recent harvest levels indicate that brown and black bears occur at low to high densities, depending on habitat (ADF&G, 1984). Both species occasionally infringe on human settlements, and troublesome animals are eliminated to protect life and property.

3.4.3.1.1 Glennallen Study Area

Large-mammal habitat values in the Glennallen study area are generally low (Evans and Cuccarese, 1977; ADF&G, 1973; Tobey, 1986). However, the study area is rich in lichen and provides prime wintering habitat for large aggregations of caribou from the Nelchina herd (Figure 3-29). These aggregations range throughout the Lake Louise Flats and midsections of the Gakona and Chistochina drainages between December and April (Pitcher, 1982). The areas around Crosswind and Twin Lakes are important movement zones during the winter migration period. Approximately 207 caribou were harvested from the general vicinity of the study area during the winter subsistence hunt in 1983-84 (ADF&G, 1986b).

Site-specific information is lacking on the status of moose subpopulations of the Glennallen and Lake Louise Flats area. Moose in this region reportedly concentrate in riverine habitats along the Tazlina River (ADF&G, 1973).

The relatively level terrain, wetness, and limited forested habitats indicate that the Glennallen study area provides marginal habitat for black and brown bears. Black bear numbers are believed to be low to moderate (Tobey, 1986). Brown bear numbers are low compared with those of areas in the Copper River lowlands, which support moderate to high populations (ADF&G, 1986b). Both black and brown bears frequent Glennallen population centers, posing an increasing problem as human settlements and development have expanded.



Source: ADF&G 1972

FIGURE 3-29 PRIME WINTERING HABITAT OF THE NELCHINA CARIBOU HERD, GLENNALLEN STUDY AREA

3.4.3.1.2 Gulkana Study Area

The Gulkana study area provides a greater mix of habitats than the Glennallen study area; an extensive spruce-hardwood forest borders the Gulkana and Gakona River systems, and large muskegs occur among the flats that separate the two systems. These two narrow river valleys provide high-quality browse for caribou and moose and function as movement zones for these species, as well as for bears.

Caribou move through and intermittently occupy the valley bottoms and surrounding upland portions of the study area during the midwinter and early spring periods (Hemming and Morehouse, 1976). Moose occur in moderate abundance all year, with higher densities reported along river systems (Figure 3-30) during late winter and early spring (ADF&G, 1973). Black bears and brown bears occur in moderate abundance throughout the study area (ADF&G, 1973).

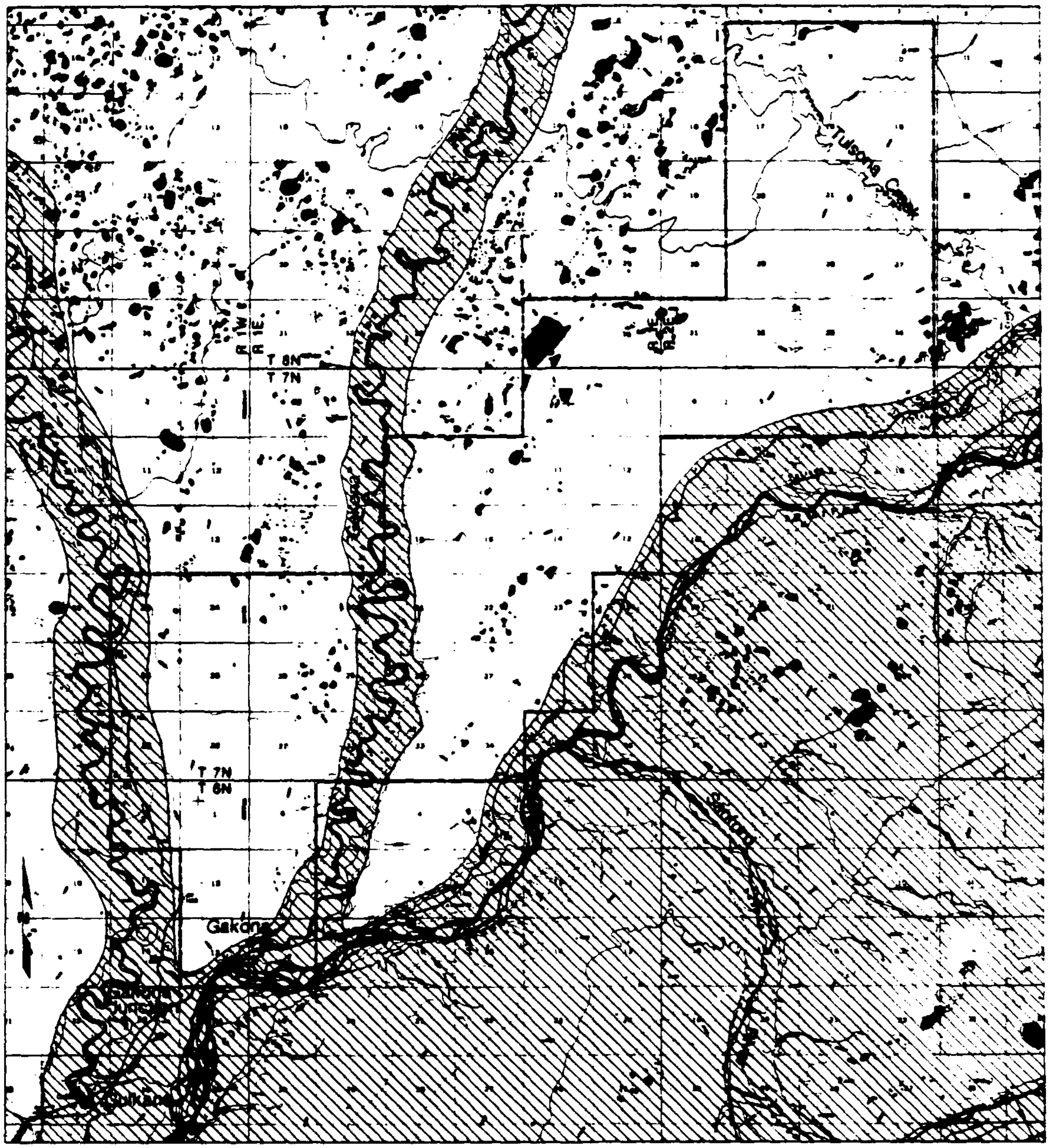
3.4.3.1.3 Indian Creek Study Area

The upland portion of the Indian Creek study area provides important caribou habitat. Large aggregations of the Nelchina Caribou herd use this area as late winter range and as a movement zone to and from other winter ranges during late winter and early spring. The southern part of the study area is in the pathway of caribou moving east and west during the winter and spring periods, respectively (Tobey, 1986). Major aggregations of the Nelchina herd seasonally traverse the Indian Creek foothills north of the Glenn Highway.

Moose are widely distributed within the northern subalpine and alpine parts of the study area in summer and on the adjacent valley floors in winter (ADF&G, 1973). Brown and black bears are seasonally abundant, with moderate to high concentrations occurring as salmon spawning peaks during July. The eastern half of the study area apparently supports greater bear numbers than the western half as a result of better feeding conditions, particularly during summer and fall.

3.4.3.1.4 Paxson East Study Area

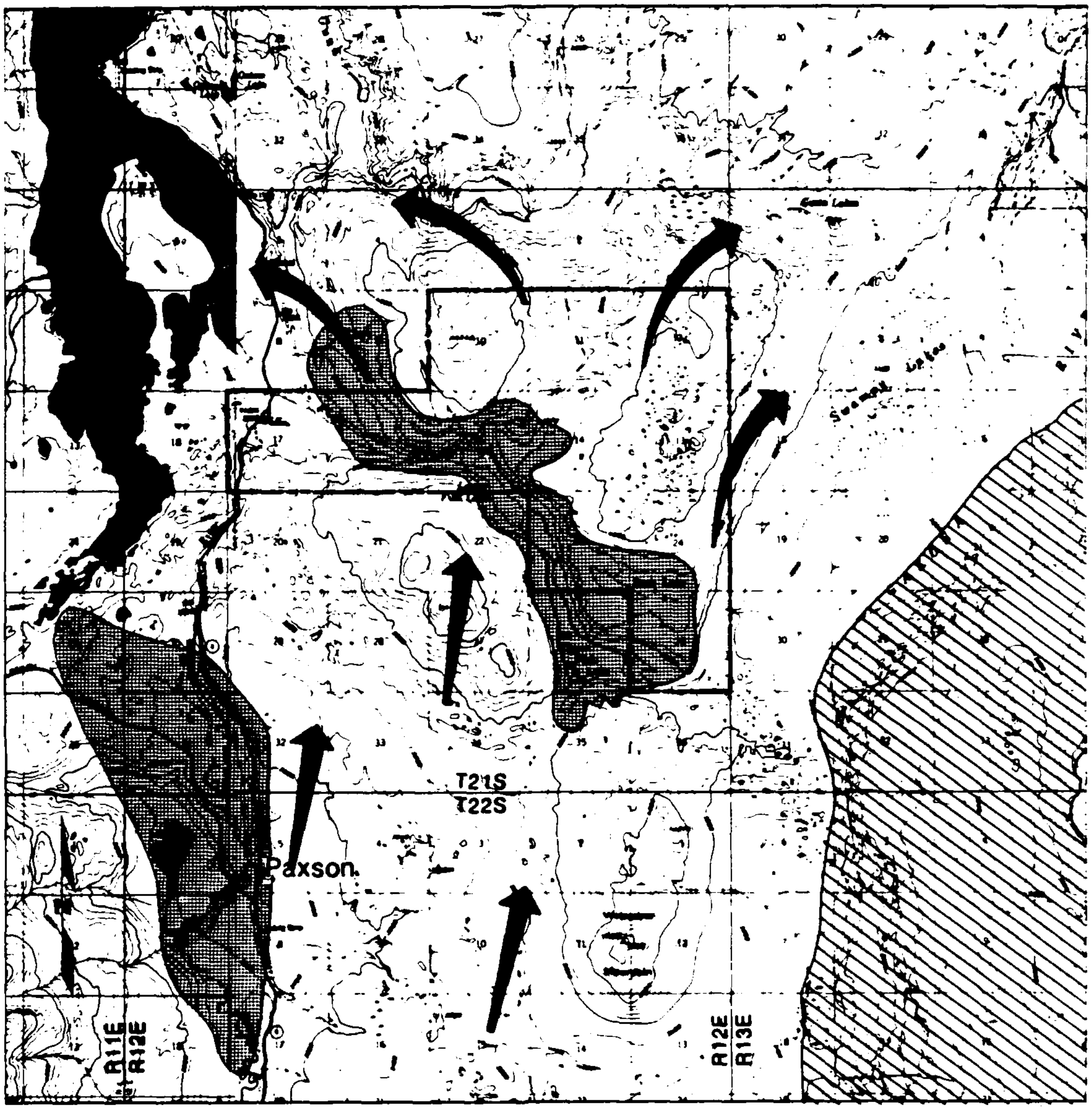
The Nelchina caribou herd uses the Paxson East study area as winter range and as a movement zone (Figure 3-31) during spring and late fall (Hemming and Morehouse, 1976; ADF&G, 1973). Small to medium-sized aggregations may be present from October through December, as well as in March and April, depending on consistency of migration patterns; consequently, parts of the area may be considered important caribou habitat. Site-specific information on the relative number of caribou using the area is unavailable.



Source: ADF&G, 1972

Moose concentration during winter

FIGURE 3-30 PRIME WINTER MOOSE HABITAT, GULKANA STUDY AREA



Source: ADF&G, 1972, Hemming and Morehouse, 1976

0 2 4
Scale in Miles

0 5
Scale in Kilometers

High moose density

Winter movement pattern of caribou

High brown bear density

FIGURE 3-31 BIG GAME USE, PAXSON EAST STUDY AREA

Moose are present all year; a high-density moose area exists several miles east of the Paxson East study area in the adjacent Gakona River drainage (Figure 3-31).

Hemming and Morehouse (1976) reported brown bear concentration areas in the Fish Lake drainage and Rock Lake basin systems. Aside from concentrated use of fish streams, adjacent alpine areas and subalpine slopes probably receive intensive use by brown bears during the spring, summer, and fall (ADF&G, 1973). The density and distribution of black bears are probably limited by the predominance of open terrain, as well as by competition with brown bears for food.

3.4.3.1.5 Tok Study Area

Caribou use of the Tok study area appears unlikely since the Fortymile herd ranges to the north and east between the White Mountains and the southwest Yukon Territory (Hemming, 1971; ADF&G, 1986b). In recent years, small bands associated with the Nelchina herd and the minor Chisana and Mentasta herds have spent a portion of the winter season in the upper Tanana Flats, primarily in the vicinity of Northway and Dot Lake south of the Tok site (Kelleyhouse, 1985; Tobey, 1986).

The mosaic of spruce-hardwood, riparian scrub, and wetland habitats that characterize the upper Tanana basin provides important habitats for moose and bear (ADF&G, 1986b). Marshland and other openings support aquatic and other types of herbaceous cover that make the upper Tanana highly productive for these big-game animals.

In spring, moose calve in the riparian areas along the Tanana and lower Tok Rivers. Lowland habitats here provide food and cover throughout summer. Moose density is moderate to high in this part of the upper Tanana valley (Kelleyhouse, 1985). A 1980 census provided an estimated density of 1 moose per square mile and more than 500 moose within and around the study area. During the 1983-84 season, 55 bull moose were taken from the Tok and Little Tok drainages (Kelleyhouse, 1985).

Black bears occur at relatively high densities in the study area, especially in timbered valleys (Kelleyhouse, 1985; ADF&G, 1986b). Black bears concentrate in riparian areas soon after leaving winter dens in May. South-facing slopes and embankments, as well as gravel bars having extensive patches of forbs and sedges, are favored early summer feeding places. In June, bears disperse in search of berry patches, which occur throughout the flats wherever suitable open areas exist.

The harvest of black bears is low, with hunting activity largely restricted to road systems and navigable rivers. Most of the 20-plus black bears taken annually in the regional game management unit are from the Tok and Tanana drainages (Kelleyhouse, 1984a).

3.4.3.2 Furbearers

The Copper and Tanana River lowlands support 11 furbearing species. These occur at different levels of abundance in response to the quality of habitat and availability of food sources (ADF&G, 1986b; U.S. Fish and Wildlife Service, 1985a; Stephenson, 1984). The Alaska Range also has the potential of supporting the same furbearers, but elevation differences and associated habitat limitations reduce the likelihood that all 11 furbearers range in the Paxson East locality in any significant number. Generally, broad lowland valleys, bordered by rolling terrain and containing dense to open forests interspersed with riverine and meadow habitats, support the greatest densities and species diversity. At least five species (marten, fox, lynx, mink, and muskrat) have a major role in regional economies, and outlying Alaska settlements, such as Glennallen and Tok, generally derive considerable monetary and recreational values from these resources.

Spruce forests with small openings provide important habitat for lynx and marten, the two furbearers sought most by trappers in south-central and interior Alaska. Other furbearers are abundant in riparian lowlands containing a mixture of spruce-hardwood forests, open meadows, and scrub. Wide-ranging species such as coyote, lynx, fox, wolf, and wolverine frequent these and more open, flatland habitats, particularly along river and lake systems. Since wolf and wolverine travel widely and use a variety of habitats, they occur at relatively low densities and require a greater variety of food resources.

3.4.3.2.1 Copper River Region

Information on furbearer population status for this portion of Game Management Unit (GMU) 13 is limited by agency funding and the absence of practical inventory methods. During the 1980-81 period, Glennallen trappers reported low to moderate beaver densities (Machida, 1982). Muskrat densities were reportedly low to moderate, compared with moderate to high mink densities; the Glennallen area was one of three areas in southcentral Alaska that reported the highest catch per mink trapper during 1980-81 (Machida, 1982). Red fox and coyote also occur in low to moderate abundance (Machida, 1982). Lynx and wolverine trappers reported low to moderate abundance, and only several catches per trapper were recorded during the 1980-81 season (Machida, 1982). During the 1982-83 period, the wolf population in GMU 13 increased slightly, with an estimate of 120 to 135 wolves comprising 25 to 30 packs; preliminary harvest data indicated that 90 wolves were taken during 1982-83 (Tobey, 1984).

Although site-specific information on furbearers is scant for the Copper River lowlands, lynx, beaver, muskrat, and mink are apparently the most important furbearers inhabiting the Glennallen and Gulkana study areas. The riparian areas of the Gulkana River and its tributaries are important feeding and travel corridors for carnivorous

furbearers. Marten, fox, and coyote probably would be more abundant in the Indian Creek study area--because of better habitat conditions--than in the low, open, and often wet terrain typical of the Glennallen and Gulkana study areas.

3.4.3.2.2 Paxson East Study Area

Information on the abundance of furbearers in the Paxson East study area is lacking. Higher elevation and limited topographic variation within this relatively small area, together with limited cover and food resources, would impede most furbearers from reaching significant numbers. Wolves and wolverines probably pass through this area. Mink and beaver may occupy the lower shrub-covered extremity of Fish Creek, but only in small numbers because of marginal habitat. Muskrat occurrence appears unlikely in the absence of suitable substrate and aquatic vegetation. The Summit Lake and Gulkana River areas apparently provide better habitat conditions for water-oriented furbearers, including land otter, as well as for fox, coyote, and lynx.

3.4.3.2.3 Tok Study Area

The Tok study area includes a diversity of habitats for all furbearers common to interior Alaska. The terrain is generally flat, with more hilly and rolling mountainous conditions to the north and east. Marten, lynx, and fox are the furbearers most eagerly sought by Tok area trappers (Stephenson, 1984).

The abundance of marten varies with local habitat conditions; high population densities are generally associated with meadow or nonforested habitat having dense herbaceous ground cover that provides an abundant supply of rodents (Stephenson, 1984). According to Kelleyhouse (1982, 1984b), marten numbers were moderately high during the 1980-81 season and declined slightly in 1982-83.

A cyclic rise of snowshoe hare numbers during the early 1980s produced an increase in lynx abundance. Lynx harvest and population numbers both peaked (Kelleyhouse, 1982, 1984b) during the 1982-83 season, when 224 lynx were taken by trappers in GMU 12. A lynx collaring study by ADF&G in 1982 indicated that lynx emigrated from the Tok River drainage in midwinter, when snowshoe hares decreased in number (Kelleyhouse, 1984b).

Fox catches were down during the 1982-83 season compared with the previous season, when numbers were reportedly high (Kelleyhouse, 1982, 1984b). The land otter harvest was low, corroborating the low density reported for GMU 12. Wolverine and wolf populations are stable; 20 to 30 wolverines have been taken annually in recent seasons from GMU 12.

Nearly all of the Tok study area is trapped, with access by snow machines and from the road systems. Virtually all tributary drainages are trapped, particularly in the vicinity of the Northway-Tetlin Flats

(ADF&G, 1986b). Muskrat populations in these flats were high in 1985 and were heavily trapped, while beaver densities were low to moderate. High beaver densities were noted in the eastern portion of the Northway-Tetlin Flats (ADF&G, 1986b).

3.4.3.3 Nongame Small Mammals

At least 27 species of small mammals are believed to occur in and adjacent to the five study areas. Because site-specific information on the population characteristics of small mammals is lacking, only general information is provided below.

Small rodents (voles, lemmings, and mice) and shrews are the most common types of small mammal in the region; they occur in all habitats containing suitable cover. Open meadows with dense herbaceous cover usually support high densities of one or more species, including singing, tundra, meadow, and yellow-cheeked voles, and brown and northern bog lemmings (Stephenson, 1984; Viereck, 1959). The numbers of small rodents numbers fluctuate in response to a combination of environmental and natural factors, ranging from climatic extremes and wildfire to disease and predation (Stephenson, 1984; Viereck, 1959; Bee and Hall, 1956; Murie, 1944). Microtine species and other small mammals (e.g., hares, marmots, and squirrels) are essential to the maintenance of predatory mammal and bird populations.

Snowshoe hares occupy forest and dense shrub habitats, avoiding large open areas. Hare populations are cyclic, with 8- to 10-year peaks of abundance. Populations in the region peaked during the early 1970s and 1980s; a mid-1980s decline is now in evidence (Kelleyhouse, 1984b).

Of the three marmots found in these regions, the hoary marmot is probably the most conspicuous. The least prevalent, woodchuck, is limited to the eastern part of Alaska, occurring chiefly in open forest areas (Bee and Hall, 1956).

Red and flying squirrels abound in forested habitats. The red squirrel depends entirely on spruce forest habitats for food (predominantly spruce seeds) and cover. The flying squirrel prefers open forested habitats containing a mixture of mature hardwoods for nesting.

Pika occupy rocky meadows and rock slides or talus slopes, generally above timberline.

Small mammals would be more diverse and abundant in the Copper and Tanana lowlands than the marginal habitats found at higher elevations in the Alaska Range. However, the Alaska Range provides habitat for larger rather than smaller rodent species. Hemming and Morehouse (1976) report the presence of a pika colony in the alpine reaches southeast of Lower Fish Lake, in the Paxson East study area. Arctic ground squirrels probably occur where clearings and good drainage prevent permafrost from reaching near the surface. Moraines and stream sides supporting grass,

sedge, and forb communities would probably be occupied by ground squirrels. Alpine and subalpine zones with rocky meadows and vegetated slopes are likely to support marmot colonies. The lower shrub land and timbered portions of this area also provide some snowshoe hare habitat, but of lesser quality than forested lowland habitat.

3.4.4 Endangered Species

An endangered race of peregrine falcon (*Falco peregrinus anatum*) breeds within the region, primarily in the Tanana River valley. In some years, the Tanana River population of peregrines was the only successfully reproducing group in the state. The Tanana valley affords relatively abundant, though scattered, nesting habitat for peregrines from the Tetlin area through most of its length; however, suitable nesting habitat (cliffs and bluffs) does not occur within the Tok study area. Nest location data have led researchers to conclude that no peregrines nest above 2,500 ft elevation in the interior of Alaska. Migrating peregrine falcons follow both the Copper and Tanana valleys during fall and spring migration movements.

The Eskimo curlew (*Numenius borealis*) is the only other federally listed endangered species that might occur in the region. Accounts of these birds are mainly historical, and some scientists believe the species to be extinct. Principal breeding grounds appear limited to the Alaska arctic coastal plain eastward into the Yukon Territory of Canada (Gabrielson and Lincoln, 1959). None have been sighted in Alaska in recent years.

3.5 Water Resources

The quantity of surface and groundwater resources in a region is largely a function of its temperature and precipitation characteristics. All five study areas lie in a continental climatic zone characterized by extreme temperatures and light precipitation (Searby, 1968; Selkregg, 1974). Annual precipitation generally ranges from 10 to 15 inches but can reach higher levels, depending on local terrain. Several hydrologic reconnaissance reports indicate that climate in the Copper River basin is transitional between the maritime and continental zones (Feulner, Childers, and Norman, 1971; Balding, 1976). The transition zone is characterized by greater precipitation totals and more moderate temperatures than the continental zone.

Mean annual precipitation ranges from 10.2 inches at Glennallen to 21.8 inches at Paxson (Table 3-4), with elevation exerting a strong influence on differences among weather stations. Most precipitation (approximately 72%) falls between June and October, with half of the annual total falling during the June-August period. The months of lowest precipitation are usually March and April. Snowfall, which averages approximately 70 inches per year, remains on the ground from mid-October to mid-May.

Table 3-4

MEAN ANNUAL PRECIPITATION AT WEATHER STATIONS NEAR STUDY AREAS

Weather Station	Nearest Study Area	Beginning Year of Record	Number of Years of Data	Mean Annual Precipitation (in.)
Glennallen	Glennallen	1965	15	10.16
Gulkana	Gulkana	1943	41	10.92
Gakona	Gulkana	1972	9	13.17
Sourdough	Gulkana	1972	10	15.59
Chistochina	Indian Creek	1904	4	11.56
Slana	Indian Creek	1958	19	16.16
Paxson	Paxson East	1978	10	21.82
Paxson Lake	Paxson East	1969	10	16.63
Tok	Tok	1959	15	10.46

Source: National Climatic Data Center, various years.

3.5.1 Surface Water

Major rivers and tributaries of the Copper River lowlands and upper Tanana River lowlands are listed in Section 3.2.1, and basin size and mean annual flows are shown in Table 3-5. The rivers generally begin freezing in mid-October and have sufficient ice for vehicle travel by early November. Ice cover normally remains in the Copper River basin until early May. Ice breakup in the Tanana River basin usually precedes that of the Copper River basin by a week or so. Breakup in the smaller tributaries may precede or follow that of the larger rivers, depending on the weather in a given year. Lakes have a longer ice-covered season, freezing up earlier and breaking up later than rivers (Nibler, 1986).

Table 3-5

CONTINUOUS STREAMFLOW DATA FOR MAJOR RIVERS IN STUDY REGION

River	Gage Location	Drainage Basin (mi^2)	Time Period (yr)	Mean Annual Flow (cfs)
Copper	Near Chitina	20,600	1955-84	37,660
Tanana	Near Tanacross	8,550	1953-84	7,945
Tazlina	Near Glennallen	2,670	1950, 52-72	4,085
Tulkana	Sourdough	1,770	1972-78, 82	1,063
Tok	Alaska Hwy Bridge	930	1952-54	285
Gakona	Gakona	620	1949-70	866

Source: Steill and Jones, 1985.

Surface runoff is the portion of precipitation that leaves a basin as streamflow (Emery, Jones, and Glass, 1985). The amount of runoff varies considerably with elevation, precipitation, local topography, vegetation, and drainage. Although estimates vary, Balding (1976) reported runoff in the Tanana basin ranging from 0.5 to 4.0 cfs per square mile, or approximately 7 to 54 inches (1 cfs per square mile is equal to 13.57 inches). Emery, Jones, and Glass (1985) reported a runoff figure of approximately 5 inches in the Copper River lowlands, with 13 to 27 inches of runoff in the higher elevations north of Paxson.

Runoff amounts are reduced considerably by large stream channel losses and high evapotranspiration in poorly drained lowlands. Near-surface permafrost effectively eliminates surface infiltration, and channel losses provide the only source of groundwater recharge in areas underlain by discontinuous permafrost. In areas of poor surface drainage, evaporative losses may effectively eliminate runoff; Anderson (1970) reports a range of 0 to 8 inches of runoff under such conditions in the Tanana basin. These losses probably account for the low average annual runoff figure (based on stream gage data) of 4 inches from the Tok River, a very sinuous, low-gradient stream.

In flat, lowland areas similar to those found in much of the study region, swampy muskeg and small, shallow lakes are common features. Runoff is very limited in these areas, and most water loss occurs through evapotranspiration (Anderson, 1970).

Areas of ice-rich permafrost (generally 50% or greater water content) may subside after thawing, which usually follows a disturbance to the insulating organic mat or vegetation layer. The creation of thaw lakes is the natural result of this process, termed "thermokarsting."

Four of the rivers flowing through the study areas--the Copper, Tanana, Tazlina, and Gakona--receive glacial melt input. This input provides year-to-year flow stability since glacial melt is higher following years of low snowfall; the flow variations that would otherwise occur are thus reduced. Glacial rivers also influence surface hydrology through diurnal fluctuations in flow occurring during the summer melt season, their sediment loading characteristics, and the potential for outburst of glacier-dammed lakes. Glacier-dammed lakes have a semi-permanent ice blockage of their outlets; failure of this barrier can unleash a torrent. The only glacier-dammed lake known to occur upstream from any of the five study areas is located on the east margin of Gakona Glacier; however, the outburst flood zone incorporates only a small area of the braided channel immediately below the glacier, far upstream from the Gulkana study area (Post and Mayo, 1971). Subglacial geothermal activity on Mt. Drum or Mt. Sanford in the Wrangell Mountains could also lead to rapid melting of ice and snow and to flooding of the Copper River through a corner of the Gulkana study area (Emery, Jones, and Glass, 1985).

Surface waters in the Tanana and Copper basins near the study areas are classified as calcium bicarbonate type (Feulner, Childers, and Norman, 1971). Dissolved-solids concentrations in the Copper River basin range from 12 to 117 mg/l, while concentrations in the Tanana basin are considerably higher (60 to 484 mg/l), with a majority of values less than 200 mg/l (Feulner, Childers, and Norman, 1971). Values less than 250 mg/l are normally considered acceptable for human uses (Balding, 1976).

The hardness of surface water generally increases along with its dissolved-solids content (Feulner, Childers, and Norman, 1971). Hardness in the Tanana basin ranges from 50 to 180 mg/l of calcium carbonate (Balding, 1976). The higher values represent winter observations, which generally are at least two or more times as high as summer values. Hardnesses in Copper River basin waters fall into a similar range (20 to 182 mg/l of calcium carbonate with peak values also seen in the winter; pH is approximately neutral (7.0), with a range of 6.4 to 7.6 (Balding, 1976).

The majority of suspended sediment is transported during peak river flows. Most suspended sediment carried by glacial rivers originates from glacial melt; the annual load of the Tanana River near Tanacross is estimated at 1,000 tons per square mile of basin (Anderson, 1970). Peak sediment transport for nonglacial lowland rivers occurs during spring breakup; the Gulkana River at Gulkana carries approximately 80 tons per square mile of basin during peak flow (Emery, Jones, and Glass, 1985). Data on sediment discharge relative to flow volumes are available for the Gulkana River at Sourdough, the Gakona River near Gakona, the Copper River near Chitna (Emery, Jones, and Glass, 1985), and the Tanana River near Tanacross (Anderson, 1970).

Emery, Jones, and Glass (1985) report the water quality of lakes in the Copper River basin to be excellent, with the exception of high suspended sediment concentrations in some lakes in glacial drainages. The lakes sampled, however, were generally large (at least 1 mi^2 in area) and connected to an adjacent river system. Closed, small lakes located in muskeg areas can be expected to have poorer water quality.

3.5.1.1 Glennallen Study Area

Hundreds of shallow lakes scattered throughout the Glennallen study area form its principal hydrologic feature. Average lake size decreases from west to east, and those in the eastern half are all under 0.25 mile in diameter. The larger lakes in the study area include part of Crosswind Lake (14 mi^2 total surface area), Twin Lakes, Mud Lake, and Island Lake. With an estimated depth of 40 ft (Emery, Jones and Glass, 1985), Crosswind Lake is probably much deeper than any of the other lakes in the study area.

The Moose Creek watershed, a system of numerous small tributaries that drains the southeastern and much of the western part of the study

area, is the largest basin in the study area. This drainage system includes Mud Lake and Twin Lakes along with numerous small lakes and connecting streams. The northwestern portion of the study area drains into the West Fork Gulkana River through Crosswind Lake. The southwestern portion drains into the Tazlina River through Tolsona Creek. No surface drainage is apparent in the northeastern quadrant of the study area.

A bend of the Tazlina River, apparently the only year-round stream in the study area, crosses the southern boundary. Twenty-two years of continuous flow data are available for the Tazlina River near Glennallen, although neither Moose nor Tolsona Creek has been gaged. Mean discharge of the Tazlina River has ranged from a few hundred to over 30,000 cfs, and surface runoff in the study area tends to be less than 5 inches (Emery, Jones, and Glass, 1985). Extensive chemical data on water quality are available for the Tazlina River; limited data are available for Moose and Tolsona Creeks. Dissolved-solids contents of the Tazlina ranges from approximately 60 to 100 mg/l, and hardness ranges from 50 to 80 mg/l.

Some of the lakes in this study area may be thermokarst features. Pewe and Reger (1983) report numerous active thaw lakes in the region.

The Tolsona mud volcanos, which consist of four mud-volcano cones and two mineral springs, form an unusual group of hydrologic features in the study area (Pewe and Reger, 1983). They are located between the Glenn Highway and Mud Lake.

3.5.1.2 Gulkana Study Area

The Gulkana study area includes numerous small lakes and portions of the Gakona, Gulkana, and Copper Rivers and Tulsona Creek. Lakes in this study area all measure less than 0.25 miles across, and most are much smaller. They are without outlets and occupy swampy, lowland areas, apparently on perennially frozen deposits.

Extensive water quality data are available for both the Gakona and Gulkana rivers. Dissolved-solids contents of these two rivers range from approximately 100 to 250 mg/l and 80 to 150 mg/l, respectively.

3.5.1.3 Indian Creek Study Area

The eastern half of the Indian Creek study area is drained by Indian Creek, which flows directly into the Copper River approximately 1 mile downstream from the southern boundary of the area. A small portion of the southeastern corner of the study area is drained by an unnamed stream flowing south into the Copper River, and a few small lakes are present.

This study area falls between the lowland study areas and Paxson East in terms of annual precipitation, runoff, and evapotranspiration.

The area appears well drained with no muskeg. Annual runoff is estimated at 5 to 10 inches (Emery, Jones, and Glass, 1985).

Water quality data from one or two observations per year over an 8-year period are available for Indian Creek. Dissolved-solids content ranges from approximately 60 to 100 mg/l.

3.5.1.4 Paxson East Study Area

Approximately 80% of the Paxson East study area drains into the Gulkana River through Fish Creek to the west and a tributary of Gunn Creek to the north. The southeastern corner of the study area drains into a tributary of the Gakona River to the southeast.

A series of three small lakes in the study area is located within the Fish Creek drainage. Rock Lake, approximately 0.75 miles long, and dozens of smaller lakes and ponds on the eastern side of the study area contain no outlets. The smaller lakes are located on a high plateau (above 4,000 ft elevation) and may have been formed through thermokarsting.

This study area differs from the others in having considerably higher precipitation (more than 20 inches), less evapotranspiration, and greater surface runoff (in all areas except the eastern plateau). Groundwater infiltration is probably low because of the likely presence of both underlying bedrock and permafrost. Streamflow information on Fish Creek is not available. Surface runoff in the study area is estimated from Emery, Jones, and Glass (1985) at approximately 27 inches.

3.5.1.5 Tok Study Area

The Tanana River forms the principal hydrologic feature of the Tok study area. Streams draining the southern portion of the study area have very low gradient and many meanders. Because of the study area's low relief, surface drainage is poor, and the majority of precipitation is probably lost either through evapotranspiration or, in areas free of permafrost, through infiltration. The latter process is most likely to occur close to the Tanana River, where alluvial deposits are probably free of permafrost. Scattered areas of muskeg appear to lack effective surface drainage.

The major tributary draining the southern portion of the site is the Tok River. Three years of continuous streamflow data collected in the early 1950s show a mean annual flow of 285 cfs, or an annual runoff of approximately 4 inches. Records show little or no flow from approximately mid-October to mid-May. A secondary, unnamed tributary to the Tanana, about 2 miles west of the Tok River, probably exhibits a similar seasonal, low runoff pattern. A third unnamed stream, draining from the mountains to the south, disappears in the wetlands in the western portion of the study area.

Flow data from the Tanana River is available continuously since 1953 from the USGS gage near Tanacross, approximately 30 miles to the west of the study area. Although a much closer gage at the Alaska Highway bridge just east of the study area was operated from 1951 through 1953, the data are insufficient for describing the area hydrologically.

Only two lakes in the region are large enough to appear on USGS maps. Both are small oxbow lakes located in the flood plain of the Tanana River.

Early water quality data on the Tanana River were collected just east of the study area; later observations were made at Cathedral Bluffs, 12 miles west of Tanacross. Dissolved-solids content of both the Tanana and Tok Rivers is high, ranging from approximately 150 to 200 mg/l.

3.5.2 Groundwater

Groundwater is used primarily for human consumption and other domestic purposes in the villages and settlements of the region. Primary sources of groundwater occur within the unconsolidated alluvium or glacial deposits in the lowland areas; more limited sources occur within thin alluvial deposits and bedrock in the mountainous areas (Balding, 1976).

The region's *discontinuous permafrost* can significantly affect the occurrence and travel paths of groundwater systems. Shallow permafrost acts as an impermeable layer preventing recharge to the groundwater system, restricting groundwater flow, and reducing the amount of groundwater in storage. In the permafrost area, groundwater may occur in shallow unconfined aquifers above permafrost, in confined aquifers below permafrost, or in more limited talik zones between frozen ground (Williams, 1970).

Recharge to the groundwater system is derived principally from precipitation. Direct infiltration of precipitation is limited in frozen ground areas; in these areas, the major recharge contribution occurs as leakage from the bottom of streams and lakes where the permafrost table is depressed or absent (Williams, 1970). Infiltration of precipitation increases during summer after the seasonal "active layer" thaws and downward migration of perched fluids or precipitation is no longer impeded.

3.5.2.1 Copper River Lowlands

A combination of low-yielding aquifers, permafrost, and poor natural water quality limit the potable groundwater sources in the Copper River lowlands. Groundwater currently used in the lowlands occurs primarily within alluvium along the stream channels and within relatively restricted sand and gravel layers in the glaciolacustrine

deposits (USGS, 1986). Potable groundwater is more likely to occur within the alluvium of major stream channels than within high glacial terrace areas (Williams, 1970). Groundwater occurring within the deeper soil zones and bedrock is generally unsuitable for human consumption.

Saline water is common in the aquifers of the Copper River lowlands. Many brackish springs discharge water high in total dissolved solids, chloride, and other salts at elevations 1,000 to 3,000 ft above sea level (Emery, Jones, and Glass, 1985). This salinity may be caused by a mixing of connate water from the underlying marine sedimentary rocks with deep, pressurized metamorphic or volcanic fluids from the Wrangell mountain area (Grantz et al., 1962). Upward flow of saline waters reduces the quality of the groundwater within the shallow, unconsolidated glaciolacustrine and alluvial deposits.

3.5.2.1.1 Glennallen and Gulkana Study Areas

In the villages along the Glenn Highway, shallow alluvial deposits adjacent to the main stream channels provide the major source of groundwater. In the villages of Glennallen, Gulkana, and Tazlina, a number of shallow wells completed at depths of less than 90 ft probably tap these deposits (USGS, 1986). Groundwater supplies from these wells are generally suitable for domestic purposes, with yields typically on the order of 10 to 20 gpm (USGS, 1986).

The natural groundwater quality of the shallow alluvial aquifer appears acceptable for human consumption, although the water is hard and commonly high in iron and manganese. These metals do not generally pose a health hazard, but high concentrations can cause staining of plumbing fixtures and textiles. The average total-dissolved-solids content of wells completed in the shallow alluvium is 250 to 300 mg/l, approximately half the 500 mg/l Alaska drinking water standard for dissolved solids (USGS, 1986). Some alluvial deposits may not support aquifers suitable for groundwater development.

The groundwater system in the town of Glennallen may be degrading in quality and quantity. These effects are most likely to be caused by inadequate septic systems and drainfields and by the depletion of storage through overuse (Lundell & Assoc., 1985). Such problems are probably restricted to the developed area.

Another significant source of groundwater in the Glennallen and Gulkana areas occurs within limited zones in the glaciolacustrine deposits. These deposits consist predominantly of low-permeability silts and fine-grained sands, but also contain interbedded, more permeable sand and gravel layers that form the principal water-producing zones within the silts. In the town of Glennallen, many wells tap these deposits between the depths of 140 and 210 ft with typical yields on the order of 10 to 100 gpm (USGS, 1986). Available data on these wells indicate a water quality similar to that of the shallower alluvial aquifer (USGS, 1986).

Deeper sources of groundwater in the Glennallen and Gulkana study areas are likely to be poor in water quality because of the regional discharge of saline waters. Two wells identified at depths of 250 and 500 ft indicate that the groundwater exceeds the drinking water standards for chloride, sulfate, total dissolved solids, and iron (USGS, 1986).

3.5.2.1.2 Indian Creek Study Area

Shallow stream deposits and glacial outwash deposits are probably the major sources of groundwater in the Indian Creek study area, with additional groundwater being sporadically available from wells drilled into bedrock. Because bedrock occurs at relatively shallow depths in much of the area, the occurrence of aquifers within the unconsolidated deposits is probably limited to the Indian Creek drainage area or the outwash terraces that lie adjacent to the stream valleys. Well yields of 10 to 100 gpm are typical of the unconsolidated aquifer deposits (Feulner, Chillers, and Norman, 1971). The yield of groundwater from bedrock is much lower, since water is generally restricted to fractures or joint systems within the bedrock; wells in bedrock typically yield less than 10 gpm (Williams, 1970).

Shallow groundwater is probably of acceptable water quality because snowmelt and seepage from Indian Creek are the major recharge sources. Deeper groundwater sources may be poorer in quality because of the regional discharge of saline waters. Because no well or water quality data are available from the immediate study area, these conditions are inferred from regional studies on water resources (Balding, 1976; Emery, Jones, and Glass, 1985).

3.5.2.2 Paxson East Study Area

In the Alaska Range, groundwater is found predominantly within alluvium in the larger river valleys. Occasionally, groundwater may occur within alluvium in smaller, unfrozen stream channels, within bedrock aquifers, or within alluvial deposits beneath frozen ground. Well yields are usually 10 gpm or less; however, wells in alluvium in the larger river valleys occasionally yield 10 to 100 gpm (Balding, 1976). Water quality is expected to be generally good in the Alaska Range because most aquifers occur within shallow alluvial deposits fed by snowmelt and surface water recharge.

In the village of Paxson, shallow wells produce groundwater from alluvium of the Gulkana River (Justice, 1986). Within the Paxson East study area, shallow groundwater may occur within the Fish Creek alluvium or beneath the Upper Fish Lake area or both because these areas are the most likely to contain thin or discontinuous permafrost. Water quality data from the Paxson Lodge indicate that iron and manganese exceed drinking water standards (Justice, 1986); these constituents commonly exceed standards in the region. Other water quality and well yield data are not available.

3.5.2.3 Tok Study Area

Groundwater is abundant in the upper Tanana River lowlands. Seepage from stream channels provides large amounts of recharge to the groundwater system, and the highly permeable sands and gravels of alluvial fan and glacial outwash deposits store and transmit large quantities of groundwater (Anderson, 1970). Groundwater also occurs in the bedrock, although these aquifers generally are less prolific.

Groundwater from the alluvial fan and glacial outwash deposits around the village of Tok provides the principal water source to the inhabitants of Tok and Tanacross. From wells drilled in this area, these deposits appear to extend to depths greater than 200 ft. The depth to groundwater appears to be roughly 30 to 70 ft in the central Tok area (Justice, 1986; USGS, 1986).

Properly designed wells in the alluvial and glacial deposits may yield groundwater on the order of 100 gpm or more from depths of less than 100 ft. Bedrock wells along the flanks of the valley supply less than 50 gpm of groundwater from depths of 50 to 500 ft (Anderson, 1970).

On the basis of historical streamflow records, recharge to the groundwater system is likely to be high in the Tok area. Gaging data at the mouth of the Tok River indicate that an average volume of 220 million gallons per day may be entering the groundwater system through seepage from the stream channels (Anderson, 1970).

In general, the natural groundwater quality in the upper Tanana River basin is good, with the best quality water apparently being obtained from the alluvial and glacial outwash deposits. The groundwater is of the calcium-magnesium-bicarbonate type and is moderately hard (Anderson, 1970); high concentrations of iron are common in many area wells.

The available well data indicate generally good water quality in the Tok study area, although iron and/or manganese may exceed the Alaska drinking water standards in some locations. The specific conductivity of a few of the Tok area wells averaged between 290 and 400 μmhos/cm (USGS, 1986, Justice, 1986). Data on total dissolved solids from one well in the Tok area indicated a level of 210 to 220 mg/l (USGS, 1986).

3.6 Air Quality

3.6.1 Environmental Setting

All the proposed ARS transmit and receive sites in Alaska are located in regions having very pristine air quality (Coutts, 1986). Because the background concentrations of contaminants for all sites are less than applicable state standards, these concentrations must be kept below those standards (Alaska Administrative Code, Title 18,

Chapter 50). Since no study area is within the more stringent Class I air quality classification areas (used for national parks and wilderness areas); therefore Class II standards apply (Table 3-6).

Currently the only sources in the study regions requiring permits are at the Trans-Alaska Pipeline pump station #10, and the power plants at Clear AFB and Healy. The power plant at Glennallen does not require a permit, and the pipeline pump station #11 planned just south of that community was never built. Pump station #10, 5 miles north of Black Rapids and approximately 45 miles south of Delta Junction, is nearest to the Paxson study area and is separated from it by the Isabel Pass along the Richardson Highway. At full capacity the pump station is designed to provide power via three J-79 gas turbine pumping units, each having 13,500 horsepower (U.S. Department of the Interior, 1973). Little if any contribution to background concentrations at the ARS site is expected from this source because the Alaska range, separates these areas into two different air basins.

The power plant at Healy is north of Cantwell along the Parks Highway. This coal-fired power plant is a 28-MW facility operated by the Golden Valley Electric Association. It used 180,000 tons of pulverized-coal to produce over 200 million kWh in 1984 (Keystone Coal Industry Manual, 1985). Although large, the fact that this source is separated from all the study areas by the Alaska Range would greatly diminish this source's contribution to background pollutant concentrations in the OTH-B areas concerned.

Another source of emissions is the coal-fired power plant at Clear AFB, Alaska, 80 miles south of Fairbanks. This plant uses 85,000 tons of coal per year (Keystone Coal Industry Manual, 1985). However, this source is sufficiently far from the study areas that little, if any, local influence can be expected.

The last and most significant source within the ARS study region is the diesel power plant owned by the Copper Valley Electric Association, which operates a facility with seven turbines at Glennallen. Two turbines each are rated at 320, 600, and 2,624 kW, respectively, and one is rated at 560 kW. All use No. 4 grade diesel fuel (Coutts, 1986).

Shown in Table 3-7 are selected 1985 quarterly fuel consumption data for these sources; the data were supplied either by the Department of Environmental Conservation Northern Region or by the operating facility itself. The estimated emission data are included in Table 3-8.

Several minor, isolated sources exist that do not require permitting by the Alaska Department of Environmental Conservation. These include small (< 9 MW) diesel generators at each of several microwave communication stations, two or three portable asphalt plants, isolated mining operations, mobile sources, and living facilities in local communities (Coutts, 1986).

Table 3-6

CLASS II ALASKA AMBIENT AIR QUALITY CONTROL STANDARDS

Pollutant	Annual Geometric Mean (mg/m^3)	Arithmetic Means ($\mu g/m^3$) Annual	Qtrly	24-hr	8-hr	3-hr	1-hr	30-min
Particulate matter	19	-	-	37	-	-	-	-
Sulfur dioxide	-	20	-	91	-	512	-	-
Carbon monoxide	-	-	-	-	10^4	-	4×10^4	-
Ozone	-	-	-	-	-	-	235	-
Nitrogen dioxide	-	100	-	-	-	-	-	-
Reduced sulfur compounds	-	-	-	-	-	-	-	50
Lead	-	-	1.5	-	-	-	-	-

Source: Alaska Administrative Code, Title 18, Chapter 50.

3.6.2 Meteorology and Climate

Few weather monitoring facilities have both consistent meteorological data and are sufficiently close location to the study areas so as to be considered wholly representative of those regions concerned (Coutts, 1986). The relevant National Climatic Center sources of local climatic data include only Anchorage, Gulkana, and Big Delta (National Climatic Center, 1984). Also, Air Force staff meteorologists have provided weather data for each candidate site in compliance with their own environmental design information requirements (U.S. Air Force, 1986). These data are given in Appendix F.

The climate of the Copper River basin of Alaska is continental (National Climatic Center, 1984). Summer temperatures are mild, with maximums generally in the 65° to 80°F range but reaching the 90° level on rare occasions. During summer there are 18 to 21 hours of daily insolation. The average freeze-free period is about 114 days, extending from mid-May to early September. A number of thunderstorms

Table 3-7

QUARTERLY FUEL CONSUMPTION RATES OF
MAJOR POWER PLANTS IN SOUTHCENTRAL ALASKA

Major Source	Fuel Type	Amount Consumed	Sulfur Content Emissions
Healy Power Plant[a]	Coal	44,263 tons	40 ppm SO_2
Clear AFB[b]	Coal	21,479 tons	0.15% sulfur avg.
Pump Station #10[a]	#2 Fuel oil	6.5 million gal	0.25% sulfur avg.
Glennallen Power Plant[c]	#4 Fuel oil[a]	260,000 gal	67 ppm sulfur

[a]Coutts (1986).

[b]Shoemaker (1986).

[c]Bettine (1986).

occur every summer, with August being the wettest month and April the driest. This pattern is due to a strong high-pressure ridge that usually develops over the Yukon Territory and greater Alaska during April and May. Moisture flowing from south to north is blocked from the interior of Alaska by the broad mountain ranges. Later in the season the wind flow begins to parallel the mountains from the southwest because of a weakening of the ridge. By August, moisture is able to pass up the Cook Inlet and around the west ends of the Alaska and Brooks Ranges. As a rule, the surface heating of the extended summer daylight and the more frequent convective activity of late summer are not conducive to the accumulation of air pollutants. Weather in the Tanana Valley is similar except cooler in winter.

The winter months are quite different; they are the times when air quality is threatened. Winters are cold, generally with 4 months of minimum temperatures below zero. The days are short and the nights are long. Spring and fall are short, with the climatic change perceptible almost daily. During the winter months, as with spring, the mountains surrounding the basin prevent a large portion of the moisture originating in the Gulf of Alaska from reaching many of the study areas. The pronounced surface cooling leads to very stable atmospheric conditions,

Table 3-8

ESTIMATED POLLUTANT EMISSION RATES

Pollutant	Healy[b,c]	Clear[b,c]	Pump Station #10[c]	Glennallen[d]
CO_2	540	255	207	113
SO_2	527	250	8.3	217
NO_x	675	320	5404	1236
HC	-[e]	-[e]	415	-[e]
TSP[f]	1,440	680	-[e]	13.8
VOC[g]	6.3	< 3	-[e]	-[e]
Methane	2.7	< 1.3	-[e]	-[e]

[a]Tons per year.

[b]Coal sulfur content of .15% assumed.

[c]Based on emission factors stated in EPA Handbook AP-42 (U.S. Environmental Protection Agency, 1985).

[d]Based on engine manufacturer's specifications.

[e]Not available.

[f]Total suspended particulates.

[g]Volatile organic compounds.

which can be conducive to the buildup of high concentrations of pollutants emitted near ground level. If there are to be significant air quality problems, they probably will occur during winter.

The only study area adjacent to a water body is the operations center planned for Anchorage. The seasons are well marked in this maritime-influenced area, with summer high temperatures averaging in the 60s and lows near 40°F. Autumn is brief, usually beginning in early

September and ending in mid-October. Temperatures begin to fall in September, with snow becoming more frequent in October. Winter can be considered as mid-October to early April when streams and lakes are frozen. Temperatures steadily decrease into January, when the highs are near 30° and lows near 10°. The coldest day in January may have a high temperature below zero. Mild days sometimes occur in winter with temperatures in the 30s. Most winter precipitation is snow, but rain may occur occasionally. Fog may occur only 15 days on the average, with ice-fog generally nonexistent. Spring or breakup is April and May, when days are warm and sunny, nights are cool, and precipitation is exceedingly small. Winds in these areas are generally light; however, some occurrences of strong winds funneling from the southeast through river gorges have been damaging (National Climatic Center, 1984).

3.7 Population

3.7.1 Copper River Valley, Alaska Range, and Tanana Valley Regions

Population levels in the region grew and ebbed with the existence of major construction projects such as the Richardson and Glenn Highways and more recently, the Trans-Alaska Pipeline. The Copper River valley and Tok region had rapid growth in the 1970s, but since 1980 population levels have stabilized.

Data from the U.S. Census of Population in 1970 and 1980, along with some population estimates for 1983, are shown in Tables 3-9 and 3-10. The geographic areas for the 1983 data differ from the Census area definitions; therefore, the changes between 1980 and 1983 do not reflect current patterns of population change.

Accounting for population in the rural areas of Alaska is difficult because of a lack of reliable and comprehensive data for small areas. There have been several special studies in recent years that cover the general areas of expected impact, but the population estimates are difficult to reconcile because of differences in defining geographic regions. However, the available estimates show general agreement for the major population centers such as Tok and Glennallen. The totals for the socioeconomic regions indicate that approximately 2,400 persons live in the Copper River valley region, 60 in the Paxson region, and 1,000 in the Tanana River region.

Future growth in population will be restricted by the lack of employment opportunities. Development of recreation and tourism facilities will lead to gradual growth; however, it will require another major construction project such as the Trans-Alaska Pipeline to boost population significantly in the next 5 years (1986 to 1991). Population projections for small communities are always highly uncertain, and the

Table 3-9

POPULATION IN THE COPPER RIVER VALLEY

	1970[a]	1980[a]	1983[b]
Junction Area			
Copper Center	206	213	439[c]
Gakona	88	87	79
Glennallen	363	511	861[c]
Glenn Highway East	-[d]	-[d]	182[c]
Gulkana	53	104	115
Lake Louise	-[d]	22	39
Tazlina	-[d]	31	30[e]
Subtotal	710	968	1,745
Lower Copper River			
Kenny Lake	-[d]	-[d]	357[c]
Upper Tonsina	-[d]	135	228[c]
Subtotal			585
Upper Copper River			
Chistochina	33	55	65
Slana	-[d]	49	43
Subtotal		104	108
Total Copper River			2,438

[a]U. S. Department of Commerce, Bureau of the Census, 1981a.

[b]Stratton and Georgette, 1985.

[c]Area boundaries not comparable with Bureau of Census boundaries used in 1970 and 1980.

[d]Not available.

[e]Alaska Department of Transportation and Public Facilities, 1985.

Table 3-10

POPULATION IN PAXSON AND THE TANANA RIVER VALLEY

	1970[a]	1980[a]	1983[b]
Paxson area			
Paxson	-[c]	30	17[d]
Sourdough	-[c]	-[c]	10
North Richardson area Highway	-[c]	-[c]	32
Total Paxson area			59
Tanana River Valley			
Tanacross	84	117	120[e]
Tetlin	114	107	110[e]
Tok	214	589	600[e]
Tok Road	-[c]	-[c]	121[b]
Mentasta	68	59	67[b]
Total Tanana River	480	872	1,018

[a]U. S. Department of Commerce, Bureau of the Census, 1981a.

[b]Stratton and Georgette, 1984.

[c]Not available.

[d]Area boundaries not comparable with Bureau of Census boundaries used in 1970 and 1980.

[e]SRI estimate.

Copper River region is no exception. Table 3-11 shows a comparison of two recent studies that projected growth in communities of the Copper River region. The earlier study (Stoltzfus, 1982) produced growth rate projections clustered about the 2% per year level, whereas the Southern Interior Regional Transportation Study (SIRTS) report (Alaska Department of Transportation and Public Facilities, 1985) projected population growth at less than 1% per year. With lower oil prices the current outlook for overall economic activity is for much slower growth than in the recent past. Therefore, the growth rates of the SIRTS report are are considered to indicate best the outlook for population growth. Applying a flat 1% per year increase to 1983 population estimates results in the population projections shown in Table 3-12.

Table 3-11

COMPARISON OF PROJECTED POPULATION GROWTH RATES

Community	Annual Average Rate of Growth (%)	
	PMS[a]	SIRTS[b]
Chistochina	2.4	–[c]
Copper Center	1.9	0.6
Gakona	2.4	–[c]
Glennallen	2.3	0.8
Gulkana	2.9	0.6
Kenny Lake	1.8	0.6
Tonsina	–[c]	0.6
Tazlina	1.9	0.0

[a]Stoltzfus, 1982.

[b]Alaska Department of Transportation and Public Facilities, 1985

[c]Not available.

Table 3-12

REGIONAL POPULATION PROJECTIONS[a]

Region	1983	1991
Copper River	2,438	2,640
Paxson	59	64
Tanana River	1,018	1,102

[a]SRI estimate from data in Tables 3-9 and 3-10.

There is a significant number of Alaskan Natives in the regions. Some communities are predominantly Native or have a large fraction of households with a Native member. Table 3-13 shows available data on the Native population in the regions for the antenna sites.

The larger communities, such as the two regional centers, Glennallen and Tok, have predominantly non-Native populations. The major Native communities in the regions are Copper Center, Gulkana, Chistochina, Tanacross, Tetlin, and Mentasta.

3.7.2 Anchorage

The 1985 population of Anchorage is estimated at 248,000, an increase of 73,000 persons or 42% over 1980. By comparison, Anchorage grew by only 48,000 persons between 1970 and 1980 (Municipality of Anchorage, 1985a). Anchorage has been growing faster than the state as a whole, which grew by about 35% between 1980 and 1985.

The Anchorage Community Planning Department has prepared three alternative population projections (Municipality of Anchorage, 1985b). These projections show a 1995 population ranging between 292,000 and 353,000, with a medium projection of 322,000. Based on the outlook for oil prices and the production of Alaskan mineral and forestry resources, it is unlikely that historical rates of growth will be maintained. The baseline projections in the Susitna project draft license application show very low rates of population growth; the 1995 population of Anchorage is projected to be only 256,400 (Alaska Power Authority, 1985).

3.8 Economy

Economic activity in the rural regions arises largely from visitors using the recreation attractions and from the government agencies managing resources. The recreation and tourism activity is seasonal, in contrast to the steady employment afforded by the federal Bureau of Land Management, the State Departments of Fish and Game and of Transportation, and local agencies such as the school districts.

Many families rely on hunting and fishing to augment their purchased food, and families that do not themselves hunt and fish often receive gifts of fish and game. Subsistence use of wild resources is described in Section 3.8.3.

In contrast, Anchorage is urban in nature with a broad economic base to serve economic activity throughout Alaska. Details of the current economies of the study areas are presented in the following sections.

Table 3-13

NATIVE POPULATION AND HOUSEHOLDS

	1980 Total Population	1980 Native Population	1983 Percentage of Households with Native Member
Copper River Valley			
Copper Center	213	85	48
Gakona	87	14	4
Glennallen	511	39	10
Glenn Highway East	-[a]	-[a]	7
Gulkana	104	43	49
Lake Louise	22	-[a]	8
Tazlina	31	4	-[a]
Kenny Lake	-[a]	-[a]	17
Upper Tonsina	-[a]	-[a]	20
Chistochina	55	27	55
Slana	49	8	6
Mentasta Lake	59	55	90
Alaska Range			
Paxson	30	0	0
Tanana River Lowlands			
Tanacross	117	101	-[a]
Tetlin	107	104	-[a]
Tok	589	90	-[a]

[a]Not available.

Sources: U.S. Department of Commerce, Bureau of Census, 1984; Stratton and Georgette, 1984.

3.8.1 Employment

3.8.1.1 Copper River Valley Region

Employment opportunities in the Copper River valley are a combination of seasonal work in the construction and recreation industries and year-round work in trade, personal services, and government services. Table 3-14 shows employment by industry in selected communities for 1980.

Glennallen has by far the largest employment count in the region because it is the center for trade, transportation, utilities, health, and education activities. The public administration sector is significant in both Gulkana and Glennallen.

Table 3-14

EMPLOYMENT OF CIVILIAN WORKERS BY INDUSTRY, 1980

Industry	Copper Center	Gakona	Glennallen	Gulkana	Tonsina	Tazlina	Total Selected
Agriculture, forestry, fishing, and mining	0	0	11	0	0	0	11
Construction	11	2	19	0	4	0	36
Transportation	0	4	17	0	9	6	36
Communication and public utilities	0	0	41	0	0	0	41
Trade, wholesale, and retail	17	0	54	0	0	0	71
Finance, insurance, real estate	0	2	8	0	0	0	10
Services							
Business & repair	0	0	0	0	7	0	7
Personal, entertainment, recreation	0	0	17	0	11	0	28
Professional health	0	0	46	0	0	4	50
Professional education	10	4	13	0	0	2	26
Public administration	6	0	31	43	0	0	80
Others	10	0	33	0	0	7	50
Total	54	12	289	43	31	17	446

Source: Alaska Department of Transportation and Public Facilities, 1985.

Stratton and Georgette (1984) estimated employment in the region by type in their survey of use of fish and game in the area. Table 3-15 summarizes their estimates for employment of heads of households in 1983. These data are based on a sample of the population and confirm the pattern in Table 3-14. They also show that a significant number of retirees live in the Copper River valley.

The "professional" category includes teachers, medical personnel, administrators, and other occupations generally requiring a college education. The "clerical/service" category covers secretarial or service positions in offices and stores. Owners and operators of businesses were classified as "merchants." The "trade" category, covering construction trades, equipment operation, and mechanics, is the dominant employment category, reflecting the importance of highway and pipeline maintenance in the region's cash economy. The "natural resources" category covers commercial fishermen and land-based occupations such as trapper, guide, farmer, and miner.

Employment in the Copper River valley is highly seasonal. According to Stratton and Georgette (1984), "Year-round employment was the exception, not the pattern in many Copper basin communities."

Table 3-16 shows the mean number of months that heads of households were employed in 1983. As is common in urban areas, many households have more than one worker. Table 3-16 also shows the mean number of months all household members were employed.

Households in Glennallen have the highest average of months employed for both the head of household and all household members. This finding would be expected because Glennallen is the region's center for retail sales, education, and medical care. Many of the employers are public agencies, and the community is less dependent on the seasonal recreation and construction sectors than other communities.

3.8.1.2 Alaska Range Region

Paxson and Sourdough are the only communities in the Alaska Range region; however, other residents live along the Richardson Highway. As shown in Table 3-15, 70% of the households in the Paxson-Sourdough region were engaged in the construction and equipment operation trades. This high percentage arises because the road maintenance station and Alascom maintenance facility located at Paxson are the only employers in the area.

Table 3-16 shows the seasonal stability of the employment base in the Alaska Range region. The mean number of months employed by the head of household in Paxson-Sourdough was second highest among the communities listed.

Table 3-15

DISTRIBUTION OF EMPLOYMENT[a]

Community/Area	N[c]	Type of Employment[b]						
		Professional	Clerical/ Service	Merchant	Skilled Trades	Natural Resources	Retired	No Information
Chistochina	22	18.2	0	0	36.4	9.1	22.7	13.6
Copper Center	27	11.1	7.4	7.4	44.4	7.4	0	22.2
East Glenn Hwy	15	13.3	13.3	13.3	33.3	13.3	13.3	0
Gakona	23	13.0	17.4	8.7	34.8	4.4	8.7	13.0
Glennallen	51	37.3	9.8	3.9	33.3	0	3.9	11.8
Gulkana	36	30.6	2.8	2.8	30.6	11.1	8.3	13.9
Kenny Lake	12	25.0	0	0	16.7	33.3	25.0	0
Lake Louise	13	7.7	7.7	30.8	15.4	15.4	23.1	0
Mentasta	19	0	5.3	5.3	26.3	5.3	21.1	36.8
Paxson-Sourdough	10	10.0	0	10.0	70.0	10.0	0	0
Slana	16	12.5	6.3	6.3	31.3	18.8	12.5	12.5
Upper Tonsina	15	20.0	6.7	0	53.3	0	13.3	6.7

[a]Percentage of heads of households among types of employmentin the Copper River Valley, 1983.

[b]See text for description of categories.

[c]Number of households surveyed.

Table 3-16

HOUSEHOLD EMPLOYMENT DATA[a]

Community/Area	No. of Households Interviewed	Head of Household[b]	Total for All Household Members[b]
Chistochina	22	5.1	7.0
Copper Center	26	7.9	13.3
East Glenn Highway	15	6.0	11.6
Gakona	22	8.3	12.1
Glennallen	50	10.9	16.2
Gulkana	32	8.0	11.8
Kenny Lake	12	7.1	9.7
Lake Louise	10	9.5	11.5
Mentasta	18	4.2	5.6
Paxson-Sourdough	10	10.1	12.8
Slana	16	8.8	11.1
Upper Tonsina	15	7.6	8.9

[a]The study period covered the 12 months from June 1982 through May 1983.

[b]Mean number of months employed, per household.

Source: Stratton and Georgette, 1985.

3.8.1.3 Tanana River Region

Economic characteristics for the region surrounding Tok are similar to those of the Copper River region. The cash economy is supported by year-round jobs in the public and retail trade sectors and seasonal jobs arising from recreation and tourism.

Quantitative employment data for the communities of Tok, Tanacross, and Tetlin are sketchy, but one can assume that the distribution among sectors is similar and that there is substantial underemployment because of seasonal fluctuations.

A survey (Haynes et al., 1984) of the Tanana valley show that the mean number of months of employment in 1983 for heads of households was 4.6 in Tanacross, 1.9 in Tetlin, and 7.1 in Tok.

3.8.1.4 Anchorage

The average level of nonagricultural employment in the Anchorage Borough was 115,550 in 1985 (Alaska Department of Labor, 1986). This is an increase of 8.5% over 1984 and 46% over 1980. Employment growth is expected to slow significantly because of recent weakness in oil prices.

Nonagricultural, civilian employment by industry sector is shown in Table 3-17. Anchorage's role as a regional center is evidenced by the dominance of the trade and services sectors. Government employment is also important, with federal, state, and local government employees comprising 23% of total employment. There are, in addition, 11,000 military personnel in the Anchorage area (Municipality of Anchorage, 1985a). This is almost 10% of civilian employment.

Unemployment averaged 7.5% in Anchorage in 1984 and dropped to 7% in 1985. Statewide unemployment rates historically have been 2 to 3 percentage points above the rate for Anchorage.

The large number of government and military employees will contribute to the stability of employment in the Anchorage area. Although cyclical fluctuations arising from weakness in the oil and gas sector will slow economic growth in future years, adverse effects will be moderated by the high percentage of employees on government payrolls.

3.8.2 Income

3.8.2.1 Copper River Valley, Alaska Range, and Tanana Valley Regions

Household incomes in the small towns and rural areas of Alaska are somewhat lower than in the urban areas. Data on income levels are available from a survey of Alaskan households taken in conjunction with the Alaska Power Authority's study of the Susitna Hydroelectric Project.

Table 3-17

ANCHORAGE NONAGRICULTURAL WAGE AND SALARY EMPLOYMENT--1985

	Number of Employees	Distribution (percent)
Mining	4,150	4
Construction	9,450	8
Manufacturing	2,800	2
Transportation, communication, and utilities	9,400	8
Wholesale trade	6,750	6
Retail trade	21,400	19
Finance, insurance, and real estate	9,000	8
Services and miscellaneous	26,400	23
Federal government	9,900	9
State government	7,050	6
Local government	9,300	8
Total	115,600	100

Source: Alaska Department of Labor, 1986.

Table 3-18 shows the distribution of household income for households that have engaged in hunting or fishing activities. The "small town" and "rural" households sampled include residents along the Alaska Highway, Glenn Highway, Richardson Highway, Tok Cutoff, and Parks Highway. Although the region surveyed is much wider than the areas that could be affected by the ARS project, economic activity throughout the survey region is similar to that in the ARS study areas.

Tok and Glennallen were included in the "small town" category of Table 3-18, and all other communities were classified as rural.

As shown in Table 3-18, the income distribution in small towns is similar to those of the Anchorage and Fairbanks urban areas; and the median income in small towns is $40,000, compared with $45,000 in the urban areas. Income in rural areas is significantly different, with a median of only $22,000. Thirteen percent of rural households had incomes of less than $10,000, with only 4% in the small towns. And the percentage of rural households with incomes of less than $30,000 (59%) is twice that of the small-town households (29%).

Table 3-18

DISTRIBUTION OF HOUSEHOLD INCOME IN ALASKA--1984[a]
(Percent)

Income	Urban[b]	Small Town[c]	Rural[d]
Under $10,000	2	4	13
$10,000-19,999	12	11	30
20,000-29,999	13	14	16
30,000-39,999	16	19	11
40,000-49,999	15	19	10
50,000 or more	42	33	20
Total	100	100	100
Median income:	$45,000	$40,000	$22,000

[a]Covers households that engaged in hunting or fishing activities--approximately 85% of small-town and rural households.

[b]Anchorage and Fairbanks.

[c]Glennallen, Tok, and 12 other towns.

[d]Includes survey results for Copper Center, Gulkana, Gakona, Paxson, Chistochina, Slana, Mentasta Lake, Tok, and Tanacross, as well as other communities on the Glenn, Alaska, and Richardson Highways.

Source: Kruse et al., 1985.

3.8.2.2 Anchorage

The cost of living in the Alaskan climate has led to wage rates and family incomes that are considerably higher than national averages. However, the standard of living is comparable to that of urban areas in the lower 48 states. Table 3-19 shows that personal income per capita in Anchorage was 63% greater than the U.S. average. Moreover, per capita income levels in Alaska grew slightly faster than the U.S. average between 1978 and 1983.

3.8.3 Subsistence

The harvest of wild resources has long been important to the region's Natives as well as to its non-Native residents. The Ahtna and Upper Tanana Indians, both Athapaskan-speaking peoples, occupied the area at Euroamerican contact. Hunting, fishing, trapping, and gathering activities set the pattern of aboriginal life and provided

Table 3-19

PERSONAL INCOME COMPARISONS

	Personal Income Per Capita 1978	Personal Income Per Capita 1983	Change 1978-1983 (percent)	1983 Percentage of U.S.
Anchorage	$12,260	$19,020	55	163
Alaska	11,150	17,225	54	147
United States	7,772	11,687	50	100

Source: U.S. Department of Commerce, Bureau of Economic Analysis, 1985.

the basis for social, cultural, and economic systems. Salmon and hare probably provided the greatest dietary contribution, but caribou, moose, goat, sheep, lynx, beaver, porcupine, and birds also were important.

Following initial contact with Russian fur traders in the late 1700s, subsistence use patterns changed little until the mid-1800s. After the Klondike gold rush in 1898, increasing numbers of non-Natives moved into the area developing new transportation corridors, new settlement patterns, and an economy based not only on the harvest of natural resources but also on cash-producing activities (Stratton and Georgette, 1984). The annual cycle changed considerably as local Natives became more oriented toward Western goods and sought better access to these goods and to temporary wage employment. Natives began congregating in permanent dwellings around mining communities and road-houses that sprang up along the transportation corridors and larger communities. These changes in settlement patterns altered the seasonal pattern in harvest movements associated with subsistence activities, and settlers moving into the area increased the pressure on the region's limited wild resources.

Over the years the economy of the study region has been marginal and subject to a number of boom-and-bust cycles. Consequently, Native residents continued their dependence on subsistence resources, not only because their social and cultural traditions were tied to the land but also for purely economic reasons, particularly during lean times. Non-Natives, as well, found the harvest of wild resources important to the successful support of their households and a valued part of the rural lifestyle.

Today, the region's economy remains marginal compared with those of Alaska's urban centers. Continued residency of many people in the region depends on an economic strategy that combines seasonal wage employment and subsistence activities. The sharing of wild foods (particularly salmon and moose) remains important to this strategy and is common within and between Upper Tanana and Copper River basin communities (Halpin, in progress; Haynes et al., 1984; Stratton and Georgette, 1984; Reckord, 1983a; Stanek, 1981), as well as with friends and relatives in urban centers like Anchorage. Subsistence foods are also shared within the context of traditional ceremonial activities, such as potlatches.

Mobility characterizes the region's subsistence users, and regional residents utilize the wide range of resources available to them. Moose, caribou, and salmon provide the bulk of resources harvested from the land. In addition to these primary resources, residents harvest a wide variety of freshwater fish, small game, birds, and other large and small animals, as well as berries and fuel wood. Table 3-20 summarizes these subsistence resources.

Several communities pursue subsistance resources in the region. These communities are described below, followed by sections discussing subsistence use for each study area. Table 3-21 summarizes selected information on subsistence harvest for the communities in the Copper River area.

Resource use data come primarily from Alaska Department of Fish and Game maps. These data do not indicate the intensity of use, and undocumented use of areas other than those depicted may occur. Because of the dynamic nature of human use patterns and changing harvest regulations, land use areas tend to fluctuate over time.

The town of Glennallen was established relatively recently at the junction of the Glenn and Richardson Highways. A study of wild-foods harvest (Stratton and Georgette, 1984) found that just 10% of the households sampled were Alaska Native. Red salmon was harvested by 45% of households and accounted for the highest proportion of household harvests (69 pounds each, or about 16 fish). This dispersed, heterogeneous community had the lowest per capita harvest at the time of the study and also was one of the least diversified in the types of resources harvested. However, a supplemental survey conducted by the Copper River Native Association of 80% of Native households in Glennallen revealed a much higher use of red salmon and big game by Native households than by non-Native households, indicating a variety of resource use patterns in the community and the importance of subsistence to some residents (Stratton and Georgette, 1984).

Table 3-20

SPECIES CURRENTLY USED FOR SUBSISTENCE

Large mammals
- Moose
- Caribou
- Black bear
- Brown bear
- Dall sheep[a]
- Mountain goat[a]
- Bison[a]

Small mammals
- Porcupine
- Arctic ground squirrel
- Lynx
- Showshoe hare
- Beaver
- Coyote
- Red fox
- Marten
- Marmot
- Mink
- Muskrat
- Weasel
- Wolverine
- Wolf

Fish
- Sockeye salmon
- Chinook salmon
- Landlocked coho salmon
- Arctic grayling
- Whitefish
- Northern pike
- Sucker
- Lake trout
- Rainbow trout
- Burbot

Birds
- Ptarmigan
- Spruce grouse
- Ducks
- Geese

Berries
- Blueberry
- Highbush cranberry
- Lowbush cranberry
- Crowberry
- Red currant
- Black currant
- Raspberry
- Nagoon berry
- Cloudberry

Mushrooms
- Orange delicious
- Shaggy mane
- Orange boletus
- Meadow mushroom
- Morel
- Puffball

Wild vegetables
- Sourdock
- Fireweed
- Watercress
- Lambsquarter
- Chickweed
- Wild chive
- Indian potato
- Sweet vetch
- Rose hips

Trees
- Spruce
- Balsam poplar
- Birch

Shrubs
- Alder
- Green willow shoots
- Willow catkin

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[a]Species that do not occur in any of the study areas but are present within the region.

Source: ADF&G, 1986c.

Table 3-21

SUBSISTENCE HARVEST OF COPPER RIVER BASIN COMMUNITIES[a]

Community	House- holds	Permanent Residents	Household Harvest (lb)	Per Capita Harvest (lb)
Glennallen	269	861	227	71
Copper Center	129	439	383	113
Upper Tonsina	76	228	305	102
Kenny Lake	68[b]	357[b]	248	78
E. Glenn Highway	65	182	404	144
Lake Louise	15	39	448	172
Gulkana	41	115	320	114
Gakona	24	79	614	192
Chistochina	27	65	311	115
Slana	16	49	679	252
Nabesna	10	37	1,233	280
Paxson-Sourdough	---	27	411	164

[a]Based on information reported in Stratton and Georgette (1984).

[b]Includes two farm cooperatives.

Copper Center, located on the Richardson Highway about 15 miles southeast of Glennallen, originated in 1896 as a small trading post. Stratton and Georgette (1984) showed the per capita and mean household harvests of resources to be relatively low among basin communities (Table 3-21). Eighty-three percent of the mean household harvest was fish, predominantly salmon, while big game comprised only 11% of the harvest. Although none of the sampled households were successful in harvesting moose in 1982, almost half reported using relatively large quantities of moose (generally ranging from 30 to 100 lb) that were obtained from friends and relatives. According to a supplemental survey of 80% of Copper Center Native households, they used fewer resources on average than did non-Native households (Stratton and Georgette, 1984). This finding may result from demographic differences between the two samples; a considerable number of Copper River Native residents are elderly and disabled, with limited mobility to participate in harvest activities.

The Upper Tonsina area includes the households along the Richardson Highway south of Copper Center to just south of the Tonsina River Lodge. Tonsina originated in the early 1900s as a roadhouse, telegraph station, and post office. Stratton and Georgette (1984) showed that resource harvest and use were relatively low, with fish comprising 58% of the harvest and big game accounting for 31%.

Kenny Lake, located between mile 1.5 and mile 15 on the Edgerton Highway, originated as a homestead community in the 1950s and 1960s. Although agriculture has not been as successful in the area as had been hoped, a number of local households still carry on some farming activities. Stratton and Georgette (1984) identified Alaska Natives in 17% of the households. Kenny Lake was found to have among the lowest subsistence harvests of the communities surveyed.

The Glenn Highway east from the boundary of the Matanuska-Susitna Borough (mile 137 to mile 180) comprises the East Glenn Highway area. Stratton and Georgette (1984) found that fish comprised 56% of the harvest, while big game reached 31%. Resource use was substantially higher than harvest, with moose and red salmon most frequently coming into the community as gifts or through nonlocal sports hunters.

Located northwest of Glennallen, Lake Louise is accessible by a 20-mile, year-round gravel road, which connects with the Glenn Highway at mile 160. The community is used primarily for recreation by people from Anchorage, the Matanuska-Susitna valley, and the Copper River basin. Stratton and Georgette (1984) found that whitefish, moose, berries, burbot, and caribou contributed the most to household harvests. A mean of 12.8 species were harvested per household, making Lake Louise the most diversified of the areas sampled in terms of resources harvested, partly because of the abundance and variety of freshwater fish in the area.

Located on the Richardson Highway about 15 miles northwest of Glennallen, Gulkana was founded in 1902 when an army telegraph station was established in an area previously used seasonally by the Ahtna. Stratton and Georgette (1984) found that Alaska Native households comprised almost 50% of the total households. Use of resources was slightly higher than harvest levels, with road-killed moose and caribou accounting for most of the difference. Gulkana showed a relatively heavy harvest of salmon compared with game, probably because of the community's location on the Copper River and a sizable population of long-term residents who have participated in the fishery for many years (Stratton and Georgette, 1984).

Gakona is located on the Glenn Highway just east of its junction with the Richardson Highway. The community's present site was occupied seasonally as a wood and fish camp by the Ahtna before establishment of a trading post and post office in 1905. Stratton and Georgette (1984) found that most households were predominately non-Native, but the community also was found to have a small Native enclave. The mean number of species harvested per household was 10.1, indicating one of the most

diversified patterns of use among the surveyed Copper basin communities. Residents were avid fishermen, and almost 75% of sampled households harvested red salmon during the study period. They also were notably successful hunters, with 56% harvesting at least one big-game animal.

Located on a bluff near the Copper River, Chistochina was originally an Ahtna fish camp. It currently consists of a small, geographically distinct Native village and a series of Native and non-Native households along Tok Road. Stratton and Georgette (1984) found that 50% of the sampled households included an Alaska Native, and that most local residents were retired, unemployed, or seasonally employed. Resource use was about 50% higher than harvest, indicating a high level of sharing (particularly of salmon) and reflecting a large number of single mothers and elderly individuals living in the community. The range of total household resource harvest was extreme, with 68% harvesting less than 100 pounds and 9% harvesting between 1,400 and 1,700 pounds. Fish comprised 45% of the mean household harvest, big game 37%, and berries and plants 12%.

Located at the junction of the Tok and Nabesna Roads, Slana was an important trading center for Upper Ahtna and Upper Tanana Indians in the early 1900s. Stratton and Georgette (1984) found that Slana households were among the most successful harvesters in the basin. Fish comprised half of the harvest, red salmon contributing the most to the mean household harvest, and big game accounted for 44%. Sixty-nine percent of households fished for freshwater fish, 63% hunted moose, and 38% pursued furbearers.

Nabesna, which originated as a mining community, is located at the foot of the Wrangell Mountains and is reached by a 42-mile unpaved road from Slana. Stratton and Georgette (1984) found that large household sizes and family businesses meant that often more than one person was employed per household. Per capita and mean household harvests were the highest among the surveyed communities, probably resulting not only from easy access to salmon and close proximity to big-game populations but also from the predominance of guiding in the local economy, indicating that residents had the requisite knowledge and means of transportation for successful harvests.

Paxson and Sourdough are located on the Richardson Highway, and both originated as roadhouses along an Army trail constructed between Valdez and Fairbanks in 1903. Stratton and Georgette (1984) found that none of the local residents were Alaska Native. Moose accounted for almost half of household harvests and was hunted by 70% of households in 1982. Although the Paxson-Sourdough sample area had a relatively lengthy average number of months employed per household head, residents there harvested and used more resources than those living in other communities with similar employment patterns, such as Glennallen. This difference may reflect the relatively easy access that local residents have to resources, and the fact that many of them own boats, all-terrain vehicles, and snow machines.

The town of Tok is located at the junction of the Alaska Highway and the Tok Cutoff to the Glenn Highway. Residents generally consider Tok's boundaries to extend in all directions, including 12 miles east along the Alaska Highway to Tetlin Junction. The community is primarily non-Native, having originated as a road construction camp in the 1940s. A sample of Tok residents who received Copper River subsistence salmon fishery permits in 1984 (Haynes et al., 1984) indicated that only 37% were employed full time in the previous 12 months. The sample also revealed that a variety of wild resources were harvested throughout the year, both in and outside of the Upper Tanana region. As Table 3-22 indicates, the subsistence resources most sought between October 1983 and September 1984 were salmon, wood and berries, moose, ptarmigan or grouse, grayling, caribou, and other plants.

Tanacross is a predominately Native community located on the west bank of the Tanana River, approximately 15 miles west of Tok. Few full-time wage employment opportunities are available in the community, with an average of just 4.6 months worked by sampled household heads during 1983 (Haynes et al., 1984). As Table 3-22 indicates, the resource categories sought most often by Tanacross residents from September 1983 to August 1984 included moose, ptarmigan/grouse, hare, whitefish, berries, wood, ducks, porcupine, plants other than berries, and furbearers. Forty-seven percent of sampled households also attempted to harvest salmon, primarily on the Copper River.

Tetlin is located on the banks of the Tetlin River, midway between Tetlin Lake and the Tanana River. It lies within the Tetlin Indian Reserve (which was established in 1930 by Federal Executive Order) and is not connected to the Alaska Highway by public road. Tetlin originated as a temporary settlement for a group of seminomadic hunters and gatherers, and the harvest cycle continues to be central to the lives of most residents. In 1984 all but two of the 107 year-round residents were of Athapaskan descent (Halpin, in progress). A 1984 household survey (Halpin, in progress) revealed that an average of only 1.9 months was worked by household heads in 1983 and that only 25% of the households contacted had annual incomes above $5,000. As Table 3-22 indicates, moose, ducks, hare, whitefish, northern pike, berries, other plants, and firewood were sought between June 1983 and May 1984 by 85% of all households interviewed.

Northway is about 50 miles southeast of Tok and 42 miles from the Canadian border. The area around Northway originally was used for seasonal camps by Athapaskan Indian bands engaged in resource harvesting activities. Employment opportunities in Northway are limited and usually occur seasonally or on a part-time basis. A 1983-84 sample of Northway households active in subsistence activities (Haynes et al., 1984), indicated that their household heads were employed an average of just 5 months during the preceding year. As Table 3-22 indicates, the

Table 3-22

UPPER TANANA RESOURCE HARVESTING ACTIVITIES

	Tanacross (N = 15)	Tetlin (N = 20)	Northway (N = 15)	Tok Permittees (N = 64)
Resource category (percent)[a]				
Moose	93	85	87	73
Caribou	40	10	20	56
Bear	13	15	13	31
Dall sheep	0	0	0	11
Ptarmigan/grouse	80	65	47	70
Ducks	57	85	60	19
Geese	6	35	20	5
Hare	80	85	60	38
Porcupine	60	25	20	3
Muskrat	7	70	73	9
Beaver	13	10	33	3
Other furbearers	53	50	67	22
Berries	73	85	87	75
Other plants	60	85	87	52
Wood	67	85	80	75
Whitefish	80	85	87	20
Grayling	13	65	67	63
Lingcod/burbot	7	70	67	29
Northern pike	47	85	80	33
Sucker	33	40	40	3
Trout	0	0	7	19
Salmon	47	20	33	87

Table 3-22 (Concluded)

Number of resource categories per household				
Range	5-14	0-17	3-19	1-20
Mean	9.3	11.9	11.3	7.9
Population	118[b]	107[b]	334[c]	589b-881[d]
Occupied households	30	28	88[c]	192b-366[d]
Mean household size	3.0	3.8	3.8	2.4-3.1
Sample size	15 (50%)	20 (71%)	15 (17%)	64 (17%-33%)
Time period	9/83-8/84	6/83-5/84	6/83-5/84	10/83-9/84

[a]The percentages represented refer to the portion of the sample populations that attempted to harvest each resource, not necessarily persons who were successful in their efforts.

[b]1980 U.S. Census

[c]Department of Community and Regional Affairs Census, January 1, 1984.

[d]Tok Public Health Center, 1983 estimates

Source: Haynes et al., 1984.

most sought-after subsistence resources between June 1983 and May 1984 were moose, whitefish, berries, other plants, northern pike, wood, muskrat, other furbearers, ling cod, grayling, ducks, and hare.

3.8.3.1 Glennallen Study Area

Documentation of wild-resource harvest activities within the Glennallen study area indicates use by residents from Glennallen, Gulkana, Gakona, Copper Center, Kenny Lake, and the Upper Tonsina, Lake Louise, and East Glenn Highway areas. Available resource use maps (ADF&G, 1986b) for the period 1964 to 1984 indicate that Crosswind Lake is used by numerous communities for freshwater fishing and that furbearers, moose, and waterfowl also are pursued in the lake's general vicinity.

Moose and caribou are hunted in the study area by several communities, some of which use virtually the whole area.

Glennallen residents appear to use a good part of the area in pursuit of a variety of wild resources. Apparently, they fish in Crosswind Lake, hunt moose around this lake as well as around Twin Lakes and along the Glenn Highway, hunt waterfowl in the Mud Lake area, and pursue caribou and furbearers throughout most of the study area.

Gulkana residents hunt moose and caribou along the Glenn Highway within the study area and pursue these resources, along with furbearers, in most of its northern portion. They also fish in Crosswind Lake (ADF&G, 1986b).

Gulkana residents use Crosswind Lake and the small lake to the east of it for freshwater fishing (ADF&G, 1986b). Snow machines provide access to these lakes (Stratton and Georgette, 1984).

Copper Center residents use Crosswind Lake for freshwater fishing and also harvest vegetation there. Furbearers, moose, and caribou are apparently pursued throughout most of the study area. Kenny Lake residents have used the western part of the Glennallen study area for hunting moose, and moose and vegetation also are sought along the Glenn Highway.

Upper Tonsina residents use the Crosswind Lake area for freshwater fishing and appear to hunt caribou throughout the northern portion of the study area, as well as in a few other scattered locations. Moose are apparently hunted in the Moose Creek drainage.

Lake Louise residents apparently fish in Crosswind Lake and harvest furbearers in the northwestern corner of the study area (ADF&G 1986b).

East Glenn Highway residents appear to use the study area to harvest numerous wild resources (ADF&G, 1986b). Apparently, the Crosswind Lake area is used in pursuit of freshwater fish, waterfowl, and furbearers. Moose are hunted throughout the study area, while caribou are pursued

along the Glenn Highway and in the western portion of the study area. Freshwater fishing also occurs in the mineral springs area.

3.8.3.2 Gulkana Study Area

Documentation of wild-resource harvest activities within the Gulkana study area indicates that it is used by a number of Copper basin communities, primarily along the transportation corridors. Resource use maps (ADF&G, 1986b) for the period 1964 to 1984 appear to indicate that the village of Gakona uses the study area for a wide variety of resources.

Most communities apparently limit their use of the study area to hunting moose and caribou along the Glenn and Richardson Highways, gathering vegetation along the same highways, and harvesting both freshwater fish and salmon from the Gulkana River. These communities include Gulkana, Kenny Lake, Chitina, Lake Louise, and the Upper Tonsina, Paxson-Sourdough, Matanuska Glacier/Sheep Mountain, and East Glenn Highway areas. Residents from Copper Center and Glennallen undertake these activities as well. However, those from Copper Center reportedly also hunt waterfowl in the extreme midwestern section of the area and those from Glennallen also harvest waterfowl along the transportation corridors and hunt moose in the northern part of the study area east of the Gakona River. Chistochina residents apparently harvest moose and caribou in the study area's extreme northwestern corner.

Residents appear to harvest a large variety of resources in the study areas. They harvest freshwater fish from the Gulkana River and up the Gakona River; salmon from the Gulkana River; vegetation along the Glenn Highway in the vicinity of the study area and up the Gakona River; moose, caribou, and furbearers throughout the area; and waterfowl east of the Gakona River and along the Richardson Highway (ADF&G, 1986b).

3.8.3.3 Indian Creek Study Area

Documentation of wild-resource harvest activities within the Indian Creek study area indicates that it is used by a number of Copper basin communities. Resource use maps (ADF&G, 1986b) for the period 1964 to 1984 indicate that the study area has been used by residents from the nearby communities of Chistochina and Slana, as well as those from the more distant communities of Copper Center, Gakona, Glennallen, Nabesna, and Upper Tonsina. Moose and furbearers are sought throughout the study area, but activities apparently focus on Indian Creek itself. Residents of Gulkana, Kenny Lake, and Mentasta apparently limit their use to taking moose, caribou, and vegetation along the Glenn Highway and in the area's extreme southeastern corner.

Chistochina residents harvest freshwater fish and moose in the study area (ADF&G, 1986b). Caribou, waterfowl, and vegetation also are harvested in the general vicinity.

Slana residents have reported hunting for moose and harvesting furbearers in the study area (ADF&G, 1986b).

Copper Center residents apparently hunt moose along the Glenn Highway and up Indian Creek to its headwaters (ADF&G, 1986b).

Gakona residents hunt moose and caribou along the Glenn Highway and use Indian Creek to its headwaters for harvesting furbearers (ADF&G, 1986b). Apparently, the southeastern corner of the study area also has been used for harvesting vegetation.

Glennallen residents apparently hunt moose, caribou, and waterfowl along the Glenn Highway and use the Indian Creek drainage for harvesting moose (ADF&G, 1986b). Caribou also is hunted in the extreme eastern portion of the study site.

Nabesna residents appear to harvest moose and furbearers as far west as Indian Creek, from its headwaters to the Glenn Highway (ADF&G, 1986b).

Upper Tonsina residents reportedly harvest caribou along the Glenn Highway south of the study area and moose in the headwaters of Indian Creek (ADF&G, 1986b).

3.8.3.4 Paxson East Study Area

Documentation of subsistence activities within the Paxson East study area is fairly limited. Mapped subsistence use data (ADF&G, 1986b) for the period 1964 to 1984 indicate that the study area is used primarily by residents from the Paxson-Sourdough area and the communities of Gakona and Glennallen. These maps indicate that residents of the Paxson-Sourdough area harvest the widest variety of resources within the study area, including freshwater fish, moose, caribou, and furbearers. Residents from Glennallen hunt moose and caribou throughout the study area as well. Gakona residents also harvest moose there, but apparently limit their caribou hunting to along the Richardson Highway. Residents from Copper Center and Kenny Lake hunt caribou, moose, and waterfowl along the Richardson Highway immediately west of the study area, and Gulkana harvesters take sheep directly south of the area.

3.8.3.5 Tok Study Area

Subsistence use within the Tok study area is less well documented than that within the other four study areas. Available information indicates that residents from the Upper Tanana communities of Tanacross, Tok, Tetlin, and Northway currently harvest subsistence resources in the general vicinity, particularly along the Alaska Highway and the Tanana River corridor (Halpin, in progress; Haynes et al., 1984; ADF&G, 1986b). Boats and highway and off-road vehicles are commonly used by local residents in their subsistence pursuits, with airplanes being used by some.

Tanacross residents may hunt small game and moose within the study area, because the Tanana River corridor is used for this purpose (Haynes et al., 1984). Although no mapped data are available showing Tok's harvest areas, its proximity to the study area means that subsistence activities undoubtedly occur there.

Tetlin residents hunt moose and waterfowl, and gather plants within the study area, primarily along the Tanana River corridor as far north as the Alaska Highway. Because motorboats provide the major mode of transport to Tok, opportunistic harvests of various resources probably occur further north within the study area as well.

Although Northway is relatively far from the Tok study area (approximately 35 miles southeast), local residents apparently harvest moose within its boundaries. This activity takes place along the Tanana River corridor as far north as, and along, the Alaska Highway (ADF&G, 1986b).

3.8.4 Recreation

The natural resources in the region attract visitors who provide vital support to the local cash economy through purchases of gas, food, lodging, and other services. Visitors can be grouped into two classes. The sightseers are generally out-of-state visitors who pass through the region purchasing mainly gas, food, and lodging. The second group consists of Alaskans and non-Alaskans who spend time in both nonconsumptive and consumptive uses of resources. These visitors may purchase guide services in addition to gas, food, and lodging. They also compete with local residents for fish and game resources in the study areas.

To understand the extent of such activity, one must rely on household surveys and visitor counts. The Alaska Department of Natural Resources (ADNR) estimates that visitation in the Copper River basin could have been as high as 600,000 in 1985 (ADNR, 1986).

In addition, ADNR estimates that 50,000 to 60,000 out-of-state visitors enter Alaska annually via the Alaska Highway, passing through Northway and Tok. The state ferry system unloads 80 to 135 private vehicles per day in Valdez during the summer months (ADNR, 1986). These vehicles must pass through the Copper River valley at least as far as Glennallen if their destination is not Valdez. Tour buses also use the Alaska and Richardson Highways. ADNR estimates that between 6 and 15 buses per day enter the Copper River basin (ADNR, 1986).

Use of fish and game resources in the Copper River-Wrangell-Valdez region by Alaskan households was surveyed for the Alaska Power Authority (Kruse, 1985). This study estimated that between 1,770 and 3,120 Fairbanks and Anchorage households engaged in fishing activity in the

region in 1984. The survey also estimated that between 2,140 and 3,600 urban households used the Lake Louise region for fishing in 1984.

Hunting activity in 1984 by urban Alaskans was estimated to have been 370 to 1,120 households in the Copper River/Wrangell/Valdez area and 700 to 1,640 households in the Lake Louise area (Kruse, 1985).

Recreational activity in the Copper River basin appears to be on the increase because of growth in Anchorage and increasing pressure on recreation areas on the Kenai Peninsula (Alaska Department of Transportation and Public Facilities, 1985).

Recreational activities by Alaskan residents are said not to have a large impact on the rural economy because Alaskan residents can bring many provisions with them and remain relatively self-sufficient (Stoltzfus, 1982). However, bush pilots, guides, and lodge owners maintain businesses of local significance based on visitors (Alaskans and out-of-state visitors) coming to the area for recreation. Although recreational activity is likely to continue to increase in the Copper River, Alaska Range, and Tanana River regions, the Alaskan residents will continue to be the most intense users. Nonresident visitors will probably continue to view these regions as an avenue to other attractions such as Mt. McKinley.

3.9 Housing

3.9.1 Copper River Valley, Alaska Range, and Tanana Valley Regions

Housing conditions vary considerably between the towns of Glennallen and Tok and the Native villages. The housing units in the villages often have limited bath and kitchen facilities by urban standards. Although many village housing units have septic tanks, numerous units still rely on privies. For example, of 845 occupied housing units in the Copper River census subarea, 362 or 43% lack complete plumbing facilities for exclusive use of the unit (U.S. Department of Commerce, Bureau of the Census, 1982).

Housing styles include conventional one- and two-story homes, "double-wide" mobile homes, log houses, and mixtures of mobile homes with wooden structures appended.

Another general feature of housing in the Copper River and Tanana River regions is a substantial number of unoccupied housing units. Some units are seasonal and not intended for year-round use, but other vacant units are available or intended for year-round use.

A general picture of housing units and occupancy can be seen in Table 3-23.

Table 3-23

NUMBER OF HOUSING UNITS, 1980

	Copper River Census Subarea	Southeast Fairbanks Census Subarea
Total housing units	1,784	2,450
Year-round units	1,434	2,112
Occupied units	845	1,660

Source: U.S. Department of Commerce, Bureau of the Census, 1982.

These census subareas include a wider area than the socioeconomic regions described in this report, but they are indicative of the large number of unoccupied units that exist in rural Alaska. Additional data on the housing units are given in Tables 3-24 through 3-26. Detailed data on occupancy are not available for the communities of Glennallen, Tonsina, Paxson, and Tok, which are "non-Native" communities. For the Native villages listed in Table 3-25, 63% of the year-round units in the Copper River valley are occupied. For Tanacross and Tetlin combined 74% of year-round units are occupied.

Table 3-26 shows the number of units that are owner-occupied (as opposed to rented) and the number of units lacking complete plumbing facilities. More than 80% of the units are owner-occupied in both the Copper River and Tanana River Valleys.

The availability of complete plumbing facilities averages about 50% for all villages in Table 3-26. There are large differences among villages, however. Some villages had sewer systems installed by the Public Health Service, but cold weather and water table conditions make it difficult to maintain systems throughout the year.

In addition to the private housing stock at Tok, housing units and other facilities remain at the Tok pump station, which was operated by the U.S. Army but is now closed. This is a 40-acre site that could be used for a power plant and other facilities needed to support an antenna site. Repairs and modifications would be necessary before existing buildings could be used.

Table 3-24

OCCUPIED HOUSING UNITS--1980

	Occupied[a] Housing Units	Persons Per Household
Copper River Valley		
Glennallen	167	2.92
Tonsina	41	3.02
Alaska Range		
Paxson	12	2.50
Tanana River Valley		
Tok	192	3.04

[a]Occupied housing units assumed to be equal to number of households in 1980 census data.

Source: U.S. Department of Commerce, Bureau of the Census, 1981b, 1984.

Table 3-25

HOUSING UNITS IN ALASKA NATIVE VILLAGES--1980

	Housing Units			Native Householder or Spouse
	Total	Year-Round	Occupied	
Copper River Valley				
Chistochina	31	29	15	9
Copper Center	125	118	77	30
Gakona	39	39	27	2
Gulkana	51	49	32	14
Slana	30	28	16	2
Tazlina	30	27	13	2
Mentasta Lake	21	17	12	11
Tanana River Valley				
Tanacross	49	39	32	28
Tetlin	35	31	27	25

Source: U.S. Department of Commerce, Bureau of the Census, 1984.

Table 3-26

CHARACTERISTICS OF OCCUPIED HOUSING UNITS
IN ALASKA NATIVE VILLAGES--1980

	Occupied Units	Owner Occupied	Lacking Complete Plumbing
Copper River valley			
Chistochina	15	6	8
Copper Center	77	61	21
Gakona	27	24	4
Gulkana	32	21	9
Slana	47	33	27
Tazlina	13	10	7
Mentasta Lake	12	7	11
Tanana River valley			
Tanacross	32	28	6
Tetlin	27	24	26

Source: U.S Department of Commerce, Bureau of the Census, 1982.

3.9.2 Anchorage

Recent growth in the housing stock of the Anchorage Borough is shown in Table 3-27. The total housing stock in 1985 is estimated at 88,804, an increase of 36% since 1980. Single-family units increased by 24%, but structures having from two to four units had the highest increase over the past 5 years with 72%.

Table 3-27

CIVILIAN HOUSING STOCK IN ANCHORAGE

Type of Structure	1980	1983	1984	1985
Single family	29,374	34,433	36,409	37,651
2-4 units	11,962	16,065	18,800	20,553
5 or more units	15,637	18,552	20,625	22,069
Mobile homes	8,103	8,865	8,809	8,531
Total	65,076	77,915	84,643	88,804

Source: Municipality of Anchorage, 1985a.

The rate of construction slowed considerably in 1985 with an increase of 4,161 units, compared with increases of 6,728 units between 1983 and 1984 and 7,262 units between 1982 and 1983.

Housing vacancy rates have fluctuated with changes in economic activity. Vacancies for all units averaged 13.5% in April 1980 but fell to 5% in mid-1983, a period of rapid growth. Pressure on the housing supply waned in 1985, with vacancies rising to 8% in mid-1985 (Municipality of Anchorage, 1985a). The vacancy rate for single-family units was 4.3%, compared with 14.4% for apartment houses having five or more units.

In addition to the civilian housing stock, there are military quarters on Elmendorf AFB. There are currently 1,864 family housing units and 1,720 spaces for unaccompanied personnel. The on-base family housing is preferred to off-base housing because of the relatively high cost of housing in Anchorage. Family housing at Elmendorf is nearly always 100% occupied.

Dormitory spaces for unaccompanied enlisted personnel total 1,720; as of early 1986, 1,460 personnel were assigned to these units. Additional dormitory space could be made available by converting transient quarters for permanent occupancy.

3.10 Community Services and Facilities

3.10.1 Education

3.10.1.1 Copper River Valley and Alaska Range Regions

The Copper River School District includes all communities for the Copper River valley and Paxson study areas. Existing facilities operated by the district are shown in Table 3-28.

Enrollment in Glennallen is down slightly (10%) from the pipeline construction period, but overall enrollment has held steady in recent years. With an average of 13 students per teacher, students in the district receive considerable personal attention. Classroom space is more than adequate except in Chistochina. A new school may be built in Slana to relieve crowding in Chistochina (Johnson, 1986).

3.10.1.2 Tanana Valley Region

The Alaska Gateway School District has schools in Tanacross, Tok, and Mentasta Lake. Current enrollments are shown in Table 3-28.

The Tanacross and Mentasta schools could accommodate a doubling of enrollment, while the Tok school could accommodate an increase of 25% (Jorgensen, 1986).

Table 3-28

COPPER RIVER SCHOOL DISTRICT ENROLLMENT

School Location	Grades	Spring 1986 Enrollment
Copper River		
Gakona	K-6	34
Glennallen	K-12	270
Chistochina	K-12	45
Copper Center	K-6	50
Kenny Lake	K-12	131
Paxson	K-12	5
District (by correspondence)	K-12	56
Tanana valley		
Tok	K-12	252
Tanacross	K-6	22
Mentasta Lake	K-12	34

Sources: Johnson, 1986; Jorgensen, 1986.

The Native village of Tetlin has a school under the jurisdiction of the Bureau of Indian Affairs. In Spring 1980, 23 students were enrolled in grades 1 through 8 (Darbyshire and Associates, 1980).

3.10.1.3 Anchorage

The Anchorage School District operates 55 elementary schools, 7 junior high schools, 6 senior high schools, and 3 facilities for alternative education programs. Student enrollment has fluctuated with population and demographic trends over the past 10 years. Enrollment in selected years is shown in Table 3-29.

Enrollment declined from more than 40,000 in 1976 to fewer than 37,000 in 1980, but has since grown to more than 42,000 in 1984 and 1985. In late 1985, significant out-migration was not expected, and enrollment was expected to continue to grow because of continued increases in the number of births in the Anchorage area (Municipality of Anchorage, 1985a). However, in June 1986, the Anchorage School District predicted an enrollment decrease of 2,000 students for September 1986 (The Anchorage Times, 1986).

Table 3-29

ANCHORAGE SCHOOL ENROLLMENT

Year	Elementary	Secondary	Special	Total
1976	21,023	17,899	1,220	40,142
1980	20,009	15,760	968	36,737
1983	21,935	17,759	1,203	40,897
1984	23,112	18,341	610	42,063
1985	23,535	18,237	654	42,426

Source: Municipality of Anchorage, 1985a.

School facilities are distributed throughout the city. There are four elementary schools on Elmendorf AFB, with a total capacity of 1,697; enrollment is currently 1,625 students, or 96% of capacity.

In Fall 1985, Anchorage School District's elementary schools were at 97% of capacity, and the secondary schools were at 93% of capacity. Overcrowding exists in the special education facilities, with membership at 115% of classroom capacity (Anchorage School District, 1986). The district opened two elementary schools in 1985. Currently, one elementary school is in the design stage, and additions to several schools are in various stages of design and construction.

In addition to the public school system, private schools in Anchorage have an enrollment of more than 2,500 students (K-8, 2,129; Grades 9-12, 417) (Anchorage School District, 1986). Corresponding capacity information is not available.

3.10.2 Transportation

3.10.2.1 Roads

The Copper River valley, Alaska Range, Tanana valley, and Anchorage are served by both highway and air travel facilities. The principal arterials that are open year round are shown in Table 3-30.

The arterial routes and "minor collector" and "local" roads are maintained by the Alaska Department of Transportation and Public Facilities. Examples of roads in these latter categories are the Lake Louise Road, Glennallen School Road, and the Copper Center Spur (Alaska Department of Transportation and Public Facilities, 1985). Traffic is heaviest in July.

Table 3-30

MAJOR HIGHWAYS IN THE STUDY REGION

Route	Communities Served	Daily Traffic[a]
Alaska Highway	Canadian Border-Tok-Fairbanks	--
Glenn Highway	Anchorage-Glennallen	700
Richardson Highway	Valdez-Glennallen-Paxson-Delta Junction	500
Tok Cutoff	Glennallen-Tok	325

[a]Traffic data averaged over 1983.

Source: Alaska Department of Transportation and Public Facilities, 1985.

3.10.2.2 Air Transportation

The state of Alaska owns several airports in the Copper River and Tanana valleys; other airports exist on private and federal lands. The only airports with asphalt runways are at Gulkana and Tok. These airports serve regional needs and have limited service (Alaska Department of Transportation and Public Facilities, 1985). Airports at Copper Center, Lake Louise, and Tazlina have gravel runways. Tanacross airport has an asphalt landing strip, and Tetlin Village has a small airstrip with service to Tok.

Anchorage is served by the Anchorage International Airport and numerous facilities for private aircraft (including float planes).

In addition, there is considerable "bush" traffic carrying people into remote locations for hunting and fishing and other recreational activities. Bush pilots often use major rivers and highways as aids to navigation.

3.10.2.3 Trail and River Transportation

Although major highways provide some access to subsistence resource areas, many locations and activities require use of motorized off-road vehicles or boats. Numerous winter and summer overland trails connect villages and highway access points with fishing, hunting, and trapping areas and camps. In some instances, winter trails are used for access between villages. The predominant mode of transportation on trails and frozen rivers is snow machines, although rubber-tired all-terrain vehicles (ATVs) are also used along with limited foot and sled traffic. Established summer trails follow well-drained pathways, which are constrained by wet tundra conditions.

The rivers form the major transportation network during summer and fall. A variety of motor boats and canoes ply the drainages, allowing access to fishing and moose-hunting areas. In winter, frozen rivers are frequently used as snowmobile trails.

3.10.2.3.1 Glennallen Study Area

Two major trail networks cross the study area. The first, running north-south, provides access from the Glenn Highway to the larger lakes along the western edge of the study area and passes along the eastern margin of Crosswinds Lake. The other runs west from the Richardson Highway south of Gulkana and branches in the study area to the southern end of Crosswinds Lake and to Ewan Lake. Supplemental trails include those established by seismic survey parties in the eastern and southern portions of the study area and minor side trails accessing cache points and traplines.

3.10.2.3.2 Gulkana Study Area

A major trail through the study area follows the terraces along the east bank of the Gakona River. Seven additional east-west and north-south seismic line trails also are present. Minor side trails also may be present.

3.10.2.3.3 Indian Creek Study Area

A trail connecting the Glenn Highway to the East Fork of the Chistochina River follows the east bank of Indian Creek through the study area, with a branch also accessing the east fork headwaters of the creek. Another trail enters the study area from the west and follows the hill flanks west of the creek. Undocumented trapline routes may also occur in conjunction with the main trail network.

3.10.2.3.4 Paxson East Study Area

The study area provides a wide variety of subsistence resources with access gained along the Fish Creek and Fish Lakes corridor into the Gakona River drainage. In addition, it is likely that branch trail routes access the Gunn Lake-Swampy Lakes area northeast of the study area. Trapline routes also may be present.

3.10.2.3.5 Tok Study Area

Knowledge about minor trail routes in the Tok study area is limited. A major winter trail connecting Tok with Tetlin crosses the southwest corner of the study area, passing through the Tetlin Hills. The Tanana River also serves as a year-round transportation corridor for boats and snow machines.

3.10.3 Water, Sewer, and Solid Waste

3.10.3.1 Copper River Valley, Alaska Range, and Tanana Valley Region

Water and sewer services to area houses vary from complete fresh-water and sewage treatment services to no services where households haul water from wells and use outdoor privies. The middle ground includes homes that draw on public or private wells and have individual septic tanks and drain fields. In general, even when there is no shortage of fresh water, water treatment and distribution systems are limited. Sewage disposal is often more of a problem because of local conditions that hamper installation and operation of septic tanks.

Sanitary landfills are available for disposal of solid wastes. In many communities, individual households must haul their solid wastes to the landfill.

There are three permitted landfills in the vicinity of the ARS study areas:

	Owner	Adjacent Study Area
Glennallen Landfill	Copper Valley Constr. Co.	Glennallen and Gulkana
Tok Landfill	J. D. Refuse Service	Tok
Tetlin Landfill	Tetlin Village Council	Tok

The Alaska Department of Transportation operates a landfill at Paxson, just south of the Paxson East study area. However, this is apparently a non-regulated landfill being operated without a permit from the Alaska Department of Environmental Conservation (Rumfelt, 1986).

There are also about 13 unpermitted and unregulated landfills located in abandoned borrow pits in the Glennallen/Gulkana area. The Alaska Department of Environmental Conservation is planning to close these landfills by restricting access and by applying a soil cover (Friedman, 1986).

3.10.3.2 Anchorage

Water treatment capacity in Anchorage is currently inadequate, but plans have been made to expand capacity to 36 million gallons per day. This capacity should meet demand well past the year 2000.

Sewage treatment capacity is currently 34 million gallons per day, and usage averages 81%. Treatment capacity should be adequate through the year 2000 under all but the highest projections for future population growth.

Solid waste disposal should be adequate well past the year 2000 because the city is opening a new 535-acre site with an expected life of 40 years.

3.10.4 Electricity

3.10.4.1 Copper River Valley, Paxson, and Tanana Valley Regions

The Copper Valley Electric Association (CVEA) provides electrical service to communities from Valdez to Gakona. Other villages have their own utilities or rely on private generation systems owned by lodges or other large businesses. Table 3-31 lists the communities served by an electric association or other seller of electricity. Two Native villages, Tetlin and Mentasta Lake, are served by community-operated electric systems developed with the help of the Bureau of Indian Affairs. Two communities, Paxson and Chistochina, have limited service provided by generators operated by the local commercial activities in the community--Paxson Lodge, Inc., (PLI) and Chistochina Trading Post (CTP).

The largest utility-type supplier is the CVEA. In 1983 it had 688 residential customers and 245 commercial or industrial customers in its Glennallen division. For 1983, CVEA-Glennallen had 7,650 kW of capacity, CTP had 535 kW, and PLI had 375 kW (Alaska Department of Commerce and Economic Development, 1985).

Although system load factors are low in all cases, PLI could not tolerate a substantial increase in peak loads. All generation in the Copper River valley and Paxson is oil fired, and therefore considerably more expensive than electricity in Alaska's urban areas. The CVEA has a new hydroelectric facility at Solomon Gulch, which is connected to the Glennallen-Valdez transmission line.

In the Tanana valley, Tanacross and Tok are served by oil-fired generation owned by Alaska Power and Telephone (AP&T). In 1983 the generating capacity at Tok was 3,525 kW. AP&T served 349 residential customers and 67 commercial/industrial customers.

3.10.4.2 Anchorage

Electric power is supplied to the Anchorage region by Anchorage Municipal Power and Light, Chugach Electric Association, and the Alaska Power Authority. Existing generating capacity is adequate to support continued growth in the Anchorage region. In 1983 the reserve capacity exceeded load by 46% (Alaska Department of Commerce and Economic Development, 1985).

Table 3-31

COMMUNITIES SERVED BY ELECTRIC UTILITIES

Community	Utility
Copper Center	CVEA[a]
Gakona	CVEA
Glennallen	CVEA
Gulkana	CVEA
Tazlina	CVEA
Tonsina	CVEA
Chistochina	CTP[b]
Paxson	PLI[c]
Tanacross	AP&T[d]
Tetlin	BIA[e]
Tok	AP&T
Mentasta Lake	Village

[a]Copper Valley Electric Association
[b]Chistochina Trading Post
[c]Paxson Lodge, Inc.
[d]Alaska Power and Telephone
[e]Bureau of Indian Affairs

Source: Alaska Department of Commerce and Economic Development, 1985.

3.11 Aesthetics

3.11.1 Aesthetic Criteria and Measures

Two factors play a key role in characterizing the visual resources of an area: scenic quality and viewer sensitivity. Scenic quality is perhaps best described as the overall impression retained after driving through, walking through, or flying over an area. Scenic quality reflects the physical features of the landscape, including both the natural features (such as landform, vegetation, water, and soils), and human modifications that have been made to the landscape (such as roads, buildings, and utility lines). These features create the distinguishable line, form, color, and texture of the landscape composition, which in turn is judged for scenic quality using criteria such as distinctiveness, variety, harmony, balance, and uniqueness.

Because a landscape may have high scenic qualities but be remotely located, viewer sensitivity is also used to represent the value of the landscape to the viewing public, including the extent to which the landscape is viewed. Sensitivity includes a characterization of the types of viewers exposed to the landscape scene, when and from where

they would see the resources, the angle and distance of the view, the frequency of view, and the range of expectations or preconceptions that viewers may have about what is being viewed. Scenic quality and sensitivity together are used as a basis for assessing impacts on visual resources.

The primary reference and method for defining visual resources is a standardized procedure developed by the Bureau of Land Management (BLM) for identifying, evaluating, and classifying visual resources for land management purposes. The BLM Visual Resource Management (VRM) System is described in BLM Manual Series 8400 (U.S. Bureau of Land Management, 1978) and is outlined in Table 3-32. The VRM System inventories and evaluates both the scenic quality and the sensitivity of a landscape. When inventoried for scenic quality, an area is first divided into subunits that appear homogeneous, generally in terms of landform and vegetation. Each area is then rated by seven key factors: landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural modification. A standardized point system assigns great, some, or little importance to each factor. The values for each category are calculated and, according to total points, three Scenic Quality Classes are determined:

- Class A areas, which combine the most outstanding characteristics of each rating factor (19-33 points).

- Class B areas in which there is a combination of some outstanding features and some that are fairly common to the physiographic region (12-18 points).

- Class C areas, in which the features are fairly common to the physiographic region (0-11 points).

Scenic quality ratings are then combined with a determination of viewer sensitivity to arrive at a VRM class. VRM classes range from I through V and reflect the management priorities for preserving existing visual qualities, with VRM I having the highest priority for preservation (See Table 3-33).

None of the ARS study areas have been assigned VRM ratings by the BLM to date; therefore, interim ratings have been assigned as part of this assessment.

Table 3-34 summarizes the scenic quality and sensitivity for each of the study areas assessed, and assigns an interim VRM class to each. The following discussion provides specific visual resource characterizations for the five study areas.

Table 3-32

VISUAL RESOURCE MANAGEMENT (VRM) SYSTEM PROCEDURE

Step	Description
Landscape Character Inventory	The landscape character, inventoried as scenic quality, is considered to be a product of the form, line, color, and texture of the land and water forms, vegetation, and structures. The specific nature and combination of these conditions determine the variety, harmony, and contrast seen in the landscape as influenced by such variable factors as season, light, scale, distance, etc.
Scenic Quality Rating	The scenic quality part of the inventory documents the character of the landscape through consideration of the condition of seven rating criteria: landform, vegetation, water, color, man-made modifications, scarcity, and influence of adjacent scenery. From this assessment, an overall level of scenic quality is determined on a rating unit basis.
Visual Sensitivity Rating	Visual sensitivity is a two-part inventory component that is used to inventory levels of use volume and user attitudes. Use volume levels are determined for key use areas and travel routes. User attitude is a consideration of the attitudes of the user public toward the visual resource values of an area and their reaction to various types of potential landscape modification.
Distance Zone	Distance zones are delineated from key viewing areas or routes. These zones establish a distance relationship between the viewer and the landscape.
Management Classes	VRM classes are determined through the combination of the scenic quality, visual sensitivity, and distance zone inventory results. These classes serve as an index to the level of visual resource values and identify acceptable levels of visual modification. VRM classes are guidelines that are used for multiple-use land planning, land management, and environmental assessments.

Table 3-32 (Concluded)

Step	Description
Contrast Rating	The contrast rating process is used to determine whether a specific project proposal would be within the VRM class limits for that area. It compares the degree of contrast or visual change between the form, line, color, and texture of the existing landform, vegetation, and structures and those proposed. This detail identifies, beforehand, specific sources of the anticipated landscape contrast and therefore provides a basis for effective and appropriate mitigation measures.

Source: U.S. Bureau of Land Management, 1978.

Table 3-33

VISUAL RESOURCE MANAGEMENT CLASSES FOR BLM LANDS

Class	Description
I	This class provides primarily for natural ecological changes. It is applied to primitive areas, some natural areas, and similar situations where landscape modifications are to be restricted.
II	Changes in any of the basic elements (form, line, color, or texture) caused by a proposed activity should not be evident in the characteristic landscape.
III	Changes in the basic elements caused by a proposed activity may be evident in the characteristic landscape. However, the changes should remain subordinate to the visual strength of the existing character.
IV	Changes may subordinate the original composition and character but must be consistent with the natural lines, textures, and other features within the characteristic landscape.
V	This class applies to areas where the naturalistic character has been so severely disturbed that rehabilitation is needed to bring it back into character with the surrounding countryside. This class would apply to areas identified in the scenery evaluation in which the quality class has been reduced because of unacceptable intrusions.

Source: U.S. Bureau of Land Management, 1978.

Table 3-34

INTERIM VISUAL RESOURCE RATING SUMMARY

Site Location	Scenic Quality Class	Viewer Sensitivity	Distance from Primary Viewing Pt.	Visual Resource Management Class[a]	Notes
Glennallen	C	Low-high	Glenn Highway runs through study area	VRM III	Most of area is more than 3 miles from public roads and of low to moderate scenic quality. Few to no distinguishable landscape features exist in the study area.
Gulkana	C	Low-high	Portions < 1 mile Tok Cutoff/ Richardson Highway	VRM III	No distinguishable landscape features; most of area not accessible to public. Portions of study area within 1 to 3 miles of major roads would have higher viewer sensitivity.
Indian Creek	B	Medium-high	< 1 mile Tok Cutoff	VRM III	Portions of site area within less than 1 mile of Tok Cutoff would have high sensitivity.
Paxson East	B	Low-high	3-5 miles Richardson Highway	VRM III	Site accessible only by jeep trail; otherwise topography masks from view of Richardson Highway.
Tok	C	Low	Alaska Highway runs through study area	VRM IV	Dominant features are surrounding ridges and mountains; dense tree coverage. Four existing LORAN antennas, 700 ft high; landscape disturbed by antenna site and roadway through area. Viewer sensitivity is high for sites within 1 mile of Alaska Highway.

[a]VRM classes are interim only and do not represent official BLM management assignments. VRM classes are a composite of the scenic quality and viewer sensitivity ratings. The VRM classes represented here are for the worst-case situation where the project site would be within 1 to 3 miles of a major roadway.

3.11.2 Glennallen Study Area

The Glennallen study area covers extensive area immediately north of the Glenn Highway and west of the Richardson Highway. The area consists of relatively flat terrain, dotted with numerous lakes, ponds, and marshes of various sizes, including the larger lakes--Twin Lakes, Mud Lake, Island Lake--and the largest, Crosswind Lake (14 mi^2 of surface area). Tolsona Creek, a tributary of the Tazlina River, forms a meandering line across the western portion of the study area. These bodies of water are surrounded by vegetation consisting primarily of small black spruce associations, which form irregular patterns of dark green color against the light patches of understory and grasses.

Human modifications to the natural landscape include the Trans-Alaska Pipeline running north-south to the east of the study area. This linear feature is visible primarily from the air. The Glennallen study area does not exhibit any visual feature of unusual or high quality. The study area is assigned an interim rating of C. Viewer sensitivity depends largely on the distance from the two major highways and ranges from high sensitivity for sites that would be within 1 to 3 miles of the highway to low sensitivity for sites more than 3 miles from the Glenn Highway.

3.11.3 Gulkana Study Area

The Gulkana study area is located north of the village of Gakona, bordered along the southeast by the Tok Cutoff and along the west by the Richardson Highway. The Gakona River runs north-south through the center of the study area, and the Gulkana River runs along its western boundary. Numerous ponds and small lakes dot the landscape. The study area topography is flat to gently sloping, with the Wrangell Mountains providing the dominant form in the distant horizon to the southeast, and the Alaska Range to the north.

Vegetation is similar to that described for Glennallen and consists primarily of small to medium-size spruce. The area does not contain any unusual scenic features. A tentative scenic quality classification of C is assigned to the Gulkana study area.

There are no paved roads into the area; however, portions of the study area are within 1 mile of the Tok Cutoff and the Richardson Highway. Viewer sensitivity ranges from low to high for the Gulkana study area, with the portions of the area located more than 1 mile from the public road having lower sensitivity.

3.11.4 Indian Creek Study Area

The area is approximately 50 miles northeast of Glennallen along the Tok Cutoff. Indian Creek is on the southern slope of the eastern portion of the Alaska Range and is a tributary of the Copper River. There is a thin mantle of vegetation among unsorted fragments from

disintegrated rock. The terrain consists of steep ridges, knolls, and gentle slopes, separated by small streams and swampy areas. Vegetation consists of heavy brush and timber (spruce), mosses, and lichens.

The rugged form of the ridges and drainages is the dominant landscape feature in the foreground, complemented by the meandering line of Indian Creek. Color and texture of the vegetation are uniform and do not exhibit unusually high visual interest. Scenic quality is tentatively rated B. Viewer sensitivity is moderate to high, with the portions of the study area within 1 mile of the Tok Cutoff having high sensitivity.

3.11.5 Paxson East Study Area

The Paxson East study area is northeast of the town of Paxson and the Richardson Highway, along the Fish Creek drainage. The study area is located at the crest of a relatively flat hilltop at an elevation of approximately 4,000 ft.

The valley sides along Fish Creek and along Upper and Lower Fish Lakes are steep. The hill on which the study area is located is composed of a very rocky till that appears to be a lateral moraine of the Gakona Glacier. Boulders and cobbles are visible over the surface, which is sparsely vegetated with mosses and lichens. Low brush occurs around small ponds and drainage channels. Dominant landscape features are the lakes (Fish, Gunn, and Swampy Lakes), Gunn Creek, the Gakona River, and a broad, flat peak (4,340 ft) in the northern portion of the study area. Scenic quality is tentatively classified as B, having distinctive features, although somewhat similar to other landscapes common to the region.

Because the Paxson East study area is located 3 to 5 miles east of the Richardson Highway and is screened from view by intervening topography, viewer sensitivity is rated as low.

3.11.6 Tok Study Area

The Tok study area is east of Tok Junction on either side of the Alaska Highway. This highway provides the main road access to Alaska from Canada.

The area is a broad, flat valley plain mantled by glacial and glaciofluvial materials of Quaternary age. The plain is bordered on the south by the Alaska Range and on the north by uplands consisting of ridges and hills. The study area is situated around the confluence of the Tanana and Tok Rivers. A layer of wind-blown silt and sand several feet thick mantles a large part of the Tok Flat. The study area is generally flat, with a few broad hills. Most of the area is low-lying and swampy, with large tracts of muskeg and occasional abandoned river channels off the Tok and Tanana Rivers. The study area is densely treed with mixed spruce, cottonwood, and birch.

Four LORAN antennas, 700 ft high, are located in the southeast corner of the study area.

Dominant landscape features are the surrounding ridges to the north and the Alaska Range to the south. Scenic quality is tentatively assigned a C rating. Viewer sensitivity ranges from low to high, with the portions of the study area within 1 mile of the Alaska Highway having a higher sensitivity.

3.12 Cultural Resources

Because few systematic studies and field surveys to inventory cultural resources have been undertaken in the upper Copper River and Tanana River basins, the available information on these resources is relatively sparse. Limited area-specific surveys in the Copper River drainage have been conducted along sections of the main rivers, highways, and the Trans-Alaska Pipeline route (Gibson and Mishler, 1984) as well as the shorelines of Paxson and Tazlina lakes. A number of sites were recorded by DeLaguna (1970) throughout the region using ethnographic sources; however, sites have not been field verified for archeological remains. The most intensive archeological work in the region has focused on the Tangle Lakes district in the McLaren River drainage west of the Paxson East study area. Archeological surveys in the upper Tanana River area near Tok have been limited to roadways, quarries, and a pumping station.

With the exception of the Tangle Lakes Archeological District, which is on the National Register of Historic Places, few sites have been evaluated for significance. It is likely that some of the identified sites, as well as some currently unidentified sites, will meet criteria established for listing in the National Register.

As a major land-holding Native corporation, Ahtna, Inc., is concerned about preserving important cultural resources on corporation and other lands in the Copper River basin. The Ahtna cultural resources specialist maintains data files on sites and will provide site-specific information as the study areas are narrowed (Alfonsi, 1986).

3.12.1 Athapaskan Land Use

The Copper River basin region was occupied at the time of Euro-american exploration by the Middle and Upper Ahtna, while the Upper Tanana occupied that portion of the study region near Tok. Although few details are available on the Ahtna subsistence-settlement pattern, DeLaguna and McClellan (1981) provide general information, stating that local groups used territories that include part of the Copper River or its larger tributaries and their hinterlands.

After spring breakup, Ahtna groups moved into fish camps along the major rivers to catch salmon with dip nets, traps, and spears. By midsummer, small groups traveled upland to meat (particularly caribou) camps, hunting small game along their routes with bows and arrows, spears, snares, and other traps. In fall, people returned to the

rivers, trapping and hunting until freezeup, when they gathered in winter houses near their fish camps. Roots, greens, and several kinds of berries were gathered in summer and fall for immediate use and storage. By February, when stored foods were exhausted, family groups moved to seek game, particularly rabbits and porcupine, and fish until breakup.

Ahtna settlements included winter villages of a few dispersed structures along with hunting and fishing camps, some of which were seasonally reoccupied. Winter villages consisted of large, semisubterranean wood houses, smaller houses and huts, pit and tree or platform caches, and a sweathouse. Temporary dwellings included double lean-tos of brush, bark, and poles, along with simple brush shelters and some hide-covered frames.

The Upper Ahtna and Upper Tanana of the study region interacted through a trail running over Mentasta Pass. In spring, before snowmelt inhibited travel, the Upper Tanana moved to fish camps near the Tanana River and hunted moose, caribou, muskrat, and beaver. In June, they dip-netted whitefish at weirs near lake outlets, drying the fish for storage in underground caches. After the fishing season, Native people collected roots and berries and hunted ducks, and in late summer hunted sheep, marmots, and ground squirrels in the mountains. The caribou hunt, undertaken in fall at caribou fences built near the timberline, was most important to subsistence, producing stores of dried meat to support Upper Tanana groups throughout the winter. Winter villages or camps were located in the uplands. Tanana house styles were similar to those of the Ahtna. More information on the Upper Tanana subsistence-settlement system is available from McKennan (1981).

Religious practices of both the Ahtna and Tanana centered on shamanism. Shamans, or Indian doctors, were thought to have spiritual power, which was used to cure illness and sometimes to bring about misfortune, illness, or death. Before Euroamerican contact, the Ahtna and Tanana cremated their dead; however, burials covered by small houses were used during the historic period.

A list of traditional place names for Ahtna territory was reported by Kari and Buck (1983), illustrating that the Ahtna used the region extensively and were intimately familiar with it. Some land forms and other places may hold historic importance for Ahtna and Tanana residents even though archeological remains may not be present. Reckord (1983b) provides an inventory of potentially important Ahtna historical and cemetery sites. Although no sites are listed for the five study areas, Reckord's research was generally limited to lands peripheral to the study areas.

3.12.1.1 <u>Glennallen Study Area</u>

DeLaguna and McClellan (1981) identified two Middle Ahtna bands occupying the area near Glennallen in the 19th century: the Tyone-Mendeltna and the Gulkana-Gakona. Appendix G provides information on

the ethnohistoric cultural resource sites near the Glennallen study area as recorded in the Alaska Heritage Resources Survey files of the State Office of History and Archeology. A reported Ahtna campsite is located within the Glennallen study area, and several sites, including cemeteries, villages, and campsites, occur within 10 miles of study area boundaries. Kari and Buck (1983) list more than 20 Ahtna names for places in or adjacent to the study area.

3.12.1.2 Gulkana Study Area

The area near Gulkana was occupied by the Gulkana-Gakona band in the 19th century (DeLaguna and McClellan, 1981). As Appendix G indicates, Gakona village and a cemetery associated with Athapaskan occupation occur within the Gulkana study area. Several sites are known or reported within 14 miles, including villages, cemeteries, and campsites. Kari and Buck (1983) list five Ahtna names for places in or adjacent to the study area.

3.12.1.3 Indian Creek Study Area

The Indian Creek study area was occupied by the Sanford River-Chistochina band in the 19th century (DeLaguna and McClellan, 1981). As Appendix G indicates, no ethnohistoric cultural resource sites within the study area have been reported, although several villages and campsites are known or reported within 10 miles of its boundaries. Kari and Buck (1983) list four Ahtna names for places in or adjacent to the study area.

3.12.1.4 Paxson East Study Area

The Paxson East study area formed part of the hinterland of the Gulkana-Gakona band during the 19th century (DeLaguna and McClellan, 1981) and was used for hunting and fishing. As Appendix G indicates, no ethnohistoric cultural resource sites within this study area have been reported, although a cabin with cache or housepit depression is located within 15 miles of the study area. Kari and Buck (1983) list five Ahtna names for places associated with Paxson.

3.12.1.5 Tok Study Area

The Tok study area is located within the historic territory of the Mansfield-Kechumstuk band and bordering that of the Tetlin-Last Tetlin band (McKennan, 1981). As Appendix G indicates, no ethnohistoric cultural resource sites within this study area have been reported, although a Tanana cache pit that includes burned bone and wood fragments is located within 15 miles of the study area.

3.12.2 Prehistoric Resources

The prehistory of the Copper River basin and upper Tanana River is not well known. No archeological evidence in the Copper River drainage supports human habitation before the 2,000-year-old protohistoric Ahtna occupation. However, the area was free from glaciers and large glacial

lakes at least 9,000 years ago, and evidence from adjacent drainages suggests that sites from pre-Ahtna periods are likely to be present.

The most extensive archeological work within the Copper-Tanana region has occurred in the Tangle Lakes district west of Paxson, near the divide between the McLaren, Gulkana, and Delta Rivers. More than 200 sites have been included in a National Register district, and a cultural chronology has been established covering at least the past 10,000 years (Mobley, 1982). The earliest evidence relates to the Amphitheater Mountain Complex, dating to approximately 10,000 years ago. The complex is characterized by crude bifaces and a presumed big-game hunting focus. Between 10,000 and 8,000 B.P. (before present), the area was frequented by peoples employing a core-blade lithic technology, labeled the Denali Complex. No sites have been identified dating between about 8,000 and 4,500 B.P., and it has been suggested that this period may represent a hiatus in use of the locality. Groups associated with what is termed the Northern Archaic Tradition occupied the area beginning about 4,500 B.P. with an assemblage featuring side-notched projectile points and a general absence of core-blade technology. The modern Athapaskan assemblages appeared in the area approximately 1,500 to 2,000 B.P.

In the Tanana drainage, the Dixthada site is the most studied site close to the Tok study area. The site was an Athapaskan village visited by Lieutenant Henry Allen during the 1885 explorations of the region, but it also contains an older component (dated to approximately 2,500 B.P.) that includes core and microblade technologies.

In a recent synthesis of the cultural chronology of central Alaska, Dixon (1985) proposed a generalized sequence based on work in the Susitna and Tanana drainages (Table 3-35). Sites representative of these cultural traditions or complexes could also occur in the upper Copper River basin, but current survey work is limited and, as noted above, only sites indicative of Ahtna cultural patterns have been recorded. These sites consist of winter village sites, including house depressions and cache or food storage pits, seasonal resource sites for hunting and fishing, grave sites, and trails. Identified sites are on well-drained terrace formations adjacent to major rivers, tributaries, and lakes. The overall settlement pattern, however, has not been confirmed archeologically because of the limited, area-specific nature of previous surveys (Spartz, 1985).

3.12.2.1 Glennallen Study Area

The Glennallen study area was used historically for subsistence fishing, hunting, and trapping and was probably an important location for these activities in prehistory. Only one major survey has characterized prehistoric resources in a nearby similar environment. Reger (1985) surveyed the margin of Tazlina Lake approximately 8 miles southwest of the study area and identified more than 18 prehistoric, ethnohistoric, and historic sites consisting primarily of pit houses and cache pits along the shoreline and nearby creeks. Radiocarbon dating

Table 3-35

CULTURAL CHRONOLOGY OF INTERIOR ALASKA

Cultural Tradition Complex	Diagnostic Material Culture Traits
Euroamerican Tradition Present-100 B.P.	Items of Euroamerican manufacture.
Athapaskan Tradition c. 100-1,500 B.P.	Deemphasis on stoneworking and increased used of organic materials. Intensive use of birch bark; high frequencies of fire-cracked rock; use of native copper; barbed antler and stemmed stone, bone, and copper projectile points. Absence of microblades and burins.
Late Denali Complex c. 1,500-3,500 B.P.	Wedge-shaped, tabular, and "pencil-shaped" microblade cores, microblades; burins on bifaces and flakes; burin spalls; possibly burin spall artifacts; microblade core tablets; and scrapers; notched, constricting base, and lanceolate projectile points.
Northern Archaic Tradition c. 3,500-5,000 B.P.	Side-notched projectile points; end scrapers; elongate and semi-lunar bifaces; boulder chip scrapers, large bifaces; notched pebbles; hammerstones; choppers. Absence of microblades and burins.
American Paleoarctic Tradition c. 5,000-10,600 B.P.	Wedge-shaped microblade cores; blocky rotated blade and microblade cores; microblades and blades; core tablets; burins struck on flakes; burin spalls; elongate bifaces; scrapers; straight, concave, and convex base projectile points; spokeshaves.
Chindadn Complex c. 10,600-greater than 11,000 B.P.	Bifacially flaked triangular projectile points; "tear-drop" bifaces (knives?); end and side scrapers. (Probable absence of microblades and burins.)

B.P. - Before present.

Source: Dixon, 1985.

indicates that the area has been occupied for at least 500 years, and a major village there was visited by Russian explorers. Spartz (1985) noted that a similar site pattern may occur in the area of Crosswind Lake.

No prehistoric sites have been identified within the study area. A lithic flake scatter was identified 4 miles southwest of the study area during a survey for a radio station facility; Appendix G lists prehistoric resources within approximately 10 miles of the study area.

3.12.2.2 Gulkana Study Area

The vicinity of the Gulkana study area has been studied more intensively than the other study areas. Rainey (1939) tested sites, including pit houses and cache pits, at Gulkana and Gakona. Excavations at the Ringling site (GUL-077), located 3 miles south of the study area, yielded evidence for occupation between 500 and 1,000 years ago (Workman, 1976). Identified prehistoric sites tend to occur on upper terraces adjacent to the major rivers. The Gulkana Weir site (GUL-094) is the known prehistoric site closest to the study area and may also represent an Ahtna summer camp.

Given the study area's location near the confluence of the Gulkana and Copper Rivers, it has a high potential for additional sites, particularly along the Gakona River.

3.12.2.3 Indian Creek Study Area

Only limited archeological surveying has been done in the vicinity of the Indian Creek study area, and most identified sites occur near the confluence of the Chistochina and Copper Rivers. As shown in Appendix G, the nearest known site with possible prehistoric components, including house pit depressions (GUL-028), occurs 1.3 miles south of the study area.

The distribution of known sites suggests that cultural resources could occur on terraces adjacent to Indian Creek. Other sites associated with resource procurement may be present in the uplands.

3.12.2.4 Paxson East Study Area

The Paxson East study area is located adjacent to an ethnohistoric and prehistoric travel route through the Alaska Range; evidence for use and occupation within the locality dates back more than 10,000 years. The Tangle Lakes Archeological District listed in the National Register of Historic Places lies 10 miles west of the study area.

As indicated in Appendix G, the Fish Creek site (XMH-227), containing materials associated with the Denali Complex and dating to the period 8,000 to 10,000 B.P., is located within the study area. Two additional prehistoric sites within 7 miles of the study area (XMH-221 and XMH-321) consist of lithic flake scatters that were identified during a survey for the Trans-Alaska Pipeline.

The Paxson East study area is near an area already identified as providing a significant contribution to the study of Alaskan prehistory, indicating that potentially important sites are likely to occur within the study area.

3.12.2.5 Tok Study Area

Little is known about prehistoric settlement and use in the vicinity of the Tok study area. As shown in Appendix G, sites identified within the study area include the Tanana Bridge Quarry site (TNX-026) with lithic and faunal remains underlying tephra deposits, and could relate to Denali or Late-Denali complexes predating 1,500 B.P. Other sites in and near the study area consist of small lithic flake scatters of undetermined age, most of which cluster in an area surveyed for a pumping station approximately 6 miles west of the study area.

Numerous ethnohistoric trail routes to the Copper and Fortymile River drainages, as well as along the Tanana River, intersected in the vicinity of the study area, and they presumably were well established in prehistoric times. A moderate potential exists for earlier sites in and near the study area.

3.12.3 Historic Resources

Although Euroamerican trade goods entering Alaska in the 18th and 19th centuries influenced the native lifestyle in the Copper River region, Russian attempts to explore and open the region to further development met with heavy resistance. The upriver region containing the Copper River study areas did not receive attention until Gregoriev's 1843 expedition to Tazlina Lake. This was followed in 1847-48 by the ill-fated party led by Serebrennikov; all members of that expedition were killed in the upper drainage.

Similar difficulties confronted American explorers after the acquisition of Alaska in 1867. After several abortive attempts to ascend the Copper River in the early 1880s, the area was finally traversed in 1885 by an exploring party led by Lieutenant Henry Allen. Allen's party followed the Copper River to Batzulnetas village. The party proceeded overland through Suslota Pass to the headwaters of the Tok River, finally reaching upper Tanana villages in the Tetlin Lake area (Allen, 1887). Allen noted a number of connecting trail systems, including the main cross-mountain route through Mentasta Pass; he also was the first to report on the upper Tanana River.

Allen's exploits opened the region to further exploration and development. Although there is little historical documentation, prospectors and trappers filtered into and through the Copper River drainage during the late 1880s and early 1890s (Reckord, 1983a). In 1898, a party led by Captain W. R. Abercrombie conducted a reconnaissance to establish an "All-American" route to interior gold fields and noted two existing main trails up the Copper River. One followed the bluffs along the west bank of the river; the other, known as the Millard trail, crossed overland from Copper Center, across the flats west of Mount Drum and Mount Sanford to the Slana River and through Mentasta Pass (Rohn, 1900). The former was ultimately selected for the military road and postal route. Known as the Trans-Alaskan Military Road, it was completed in 1903, along with a U.S. Signal Corps telegraph system. Members of Abercrombie's party noted miners or mining activity at Mentasta Lake (Rice, 1900) and near the headwaters of the Chistochina River (Powell, 1900). Other miners were reaching the Susitna River drainage through a trail leading up the Tazlina River, and a U.S. Geological Survey party under W. C. Mendenhall also explored the region in 1898 (Mendenhall, 1900).

The discovery of gold near Fairbanks in 1902 resulted in additional road construction. The Valdez-Fairbanks (Richardson) trail split from the Trans-Alaskan Military Road at the Gulkana River and crossed the divide at Isabel Pass. A series of roadhouses along the route provided accommodations for travelers, dog teams, and horses. Several roadhouses also served as starting points for secondary supply trails leading into the Upper Susitna basin, and many of these trails followed established native routes. The influx of miners and the development of transportation systems brought profound change to the traditional Native settlement patterns and economies.

By the 1920s, the gold rush activities had declined and trapping became a staple of the local economy. Many Ahtna families maintained winter trapline cabins adjacent to lakes within the region, including Crosswinds, Tyone, Tanana, and Tazlina Lakes, and other fertile trapping areas (Reckord, 1983b). The upper Copper and Tanana areas remained remote, receiving limited visits by itinerant traders.

World War II brought renewed activity as roads were constructed connecting the Copper River valley with the Susitna and Tanana valleys. The construction of airstrips and communication systems formed the backbone of the modern transportation network. The war also brought an influx of servicemen to the area, swelling the population of towns such as Glennallen along the main road corridor. The postwar road connection with Anchorage provided a source of jobs for valley residents but also provided the impetus for a new influx of settlers. The most recent chapter in the development of the region concludes with the construction of the Trans-Alaska Pipeline running from Valdez to Prudhoe Bay and paralleling the route of the Richardson Highway.

3.12.3.1 Glennallen Study Area

No historic cultural resources have been recorded within the Glennallen study area, although early Russian explorers and later miners traveled nearby. The study area is characterized by a series of lakes, and Crosswinds Lake in particular was noted as a location for native trapping activities in the 1920 to 1940 period. The closest recorded historic resources in the vicinity are roadhouses associated with the development of the Valdez-Eagle and Valdez-Fairbanks military road system, which runs approximately 7 miles east of the study area. No resources associated with the main transportation network are expected within the study area, although side trails may be present.

3.12.3.2 Gulkana Study Area

The Gulkana study area is adjacent to the junction of the Valdez-Fairbanks Trail with the Trans-Alaskan Military Road. As Appendix G indicates, the site of the former Gakona Roadhouse, including the existing lodge built in 1926, is within the study area, and remnants of the original trail route also may be present. The site of the Gulkana Roadhouse and remains of the Poplar Grove Roadhouse on the Valdez-Fairbanks Trail and the Tolsona Roadhouse on the Valdez-Eagle Trail are within about 2 miles. The location of an important junction in the Alaska road system in the study area suggests that there may be additional resources associated with construction and operation of the routes.

3.12.3.3 Indian Creek Study Area

No historic cultural resources are reported within the Indian Creek study area; however, resources associated with early exploration or development of the Valdez-Eagle trail may occur in or adjacent to it. The route of Allen's 1885 expedition passed within 3 miles, and his campsites of May 28 and May 29 also are nearby. Appendix G indicates that the Chistochina, Sinona Lodge, and Cobb Lake roadhouses along the Valdez-Eagle Trail are within 12 miles of the study area, and other trail features may exist.

3.12.3.4 Paxson East Study Area

The Paxson East study area is located immediately east of the Valdez-Fairbanks trail route near the summit of Isabel Pass. Although no historic cultural resources have been identified within the study area, the proximity of the trail and activities associated with supply of the Valdez Creek mining district from Paxson's and Yost's roadhouses suggest that additional historic resources, including portions of the original trail system, could occur. Appendix G indicates that four identified historic sites and structures are located within 7 miles of the study area.

3.12.3.5 Tok Study Area

No historic cultural resources are recorded within the Tok study area, although Allen boated through the area in 1885; his map (Allen, 1887) indicates that the campsite of June 14 was probably located on the south side of the river within the study area. Parties associated with Abercrombie's 1899 surveys and the construction of the Valdez-Eagle trail also passed through the area. The main trail route runs within about 4 miles to the southwest before heading to Tanacross. An alternate route used by prospectors followed an old Indian trail along a route now traversed by the Taylor Highway and may have crossed the study area.

3.12.4 Elmendorf AFB

Little is known about Tanaina Indian land use and prehistoric or premilitary historic occupations within the Elmendorf AFB boundaries. No archeological sites have been identified in the immediate vicinity of the main base compound, although prehistoric sites may occur along coastal bluffs and creek drainages (Martin, 1986).

Elmendorf Field, originally part of Fort Richardson, was the first air facility built in Alaska for a combat role. Construction began in 1940, and the first military aircraft arrived in early 1941. After the war focused on the Aleutians, the fort's mission changed to a support role. Throughout the war, it served as a major depot, supply, and transshipment point and as nominal headquarters for the Alaska Defense Command and the 11th Air Force. The base was one of the few retained after the close of the war, and it served as headquarters for the Army in Alaska until the Elmendorf facilities were transferred to the newly formed Department of the Air Force.

Some of the original facilities at Elmendorf AFB relating to the World War II effort may meet criteria for listing in the National Register of Historic Places. A base historic preservation plan has been prepared, and coordination with local and state authorities and preparation of National Register nominations are planned (Martin, 1986).

3.13 Electromagnetic Environment

The electromagnetic environment at a particular location and time comprises all the electromagnetic fields arriving there from numerous sources, both man-made and natural. Some of these fields are used for communication or for radiolocation (radar). The electromagnetic environment in a given area can be described in terms of human use of the electromagnetic spectrum there. The electromagnetic spectrum is a renewable resource having the dimensions of amplitude, time, frequency, and space. It can be used continuously. In areas large enough to permit sufficient geographical separation, the spectrum will accommodate a number of users on the same frequency simultaneously. In smaller areas the spectrum will accommodate a large number of simultaneous users only if they are separated in frequency. A high-amplitude signal can mask a low-amplitude signal on the same frequency.

The electromagnetic environment varies continuously in both time and space. Therefore, it is generally convenient to deal with averages over time and space. When there is sufficient incentive, certain features of the electromagnetic environment can be measured and documented. However, because of the high cost, attempts are seldom, if ever, made to define the electromagnetic environment simultaneously over wide frequency ranges, large geographic areas, and long time durations. Most attempts at defining the spectrum are of limited scope, aimed only at providing answers to particular questions such as, "What emitters of electromagnetic energy can be found in certain microwave bands in downtown New York City?" or "Is the man-made radio noise at this location low enough to successfully operate an HF receiving system?" or "Are the land-mobile radio bands in Chicago too crowded to accept additional users?"

Some of the man-made contributions to the electromagnetic environment in the vicinity of the study areas are intentional, but others are accidental and are incidental to some other activity. Radio signals of all sorts are intentional man-made contributions. The electromagnetic environment in the area consists in part of signals from various broadcast radio stations, from local or transient amateur and Citizens' Band (CB) operators, from air navigation aids, from passing aircraft, from satellites that provide cable TV programming, and so on. Because some signals, particularly those in the frequency range to be used by the OTH-B radar, can be reflected back to the earth at great distances by high-altitude ionospheric layers, part of the electromagnetic environment in the area consists of transmissions propagated by sky wave from stations thousands of miles away.

Unintentional man-made contributions to the electromagnetic environment are called man-made electromagnetic noise. Such noise is radiated by power lines, fluorescent lights, household lighting dimmer switches, household appliance motors, computers, hand-held calculators, and so on. A major contributor is the automobile ignition system, which radiates a pulse of energy over all the communication bands with each spark-plug firing. Because the study areas are relatively remote from great numbers of such noise sources, the man-made noise levels there are considerably lower than in a city.

Nature contributes only noise to the electromagnetic environment, but it can do so in a big way. Even when there are no local thunderstorms, lightning strokes in storm centers in Africa and South America can cause "static" in radios in Alaska, thousands of miles away. Each lightning stroke acts as a powerful transmitter covering a wide frequency band. Its "signal" propagates by sky wave to regions thousands of miles away. This noise is an intermittent major feature of the part of the electromagnetic spectrum to be used by the OTH-B radar. In the upper regions of this portion of the spectrum, noise from the sun and stars (galactic noise) is, in the absence of signals, the predominant feature of the local electromagnetic environment.

For humans to make use of some portion of the electromagnetic environment for communication, radiolocation, radionavigation, or other such purposes, the power of the signal must exceed the power of the noise in that portion of the spectrum at the receiving location. For example, one cannot hear AM radio programming unless the power in the signal from the station is greater than the atmospheric noise and the man-made noise in the receiver's bandwidth. Thus, the electromagnetic environment is generally described by the presence of the man-made signals. Overall, the study areas have relatively low signal power density.

Because the proposed action is the construction and, more importantly, the operation of a large HF radar transmitter, the potentially affected environment extends far beyond the immediate study area, and at times might include almost any part of the world. The radar's sky wave may propagate by several hops so that it could be a feature of the electromagnetic environment in the HF band at locations far removed from the study area. The potentially affected environment thus is actually the HF spectrum in distant parts of the world.

4 ENVIRONMENTAL CONSEQUENCES

4.1 Introduction

This section describes the consequences or impacts on the environment of constructing and operating the ARS. The material is organized by topic in a manner that parallels the descriptions of the environment presented in Section 3. Mitigation measures to eliminate or reduce the environmental impacts are treated as part of each topic. As in Section 3, whenever possible, material is discussed at the regional or general level to avoid repeatig material that applies to more than one study area.

The term "sector" refers to the antenna array, backscreen, groundscreen, support building, and excluded area associated with each 60^{o} arc of coverage (see Figure 2-3).

State and federal regulations pertaining to ARS environmental issues are presented in Appendix D. A summary of standard arctic construction practices can be found in Appendix H.

Air Force policy is to recognize the significance of its actions on the environment where people live, work, or engage in recreational activities. The Air Force's goal is to ensure that its actions in the interests of defense intrude as little as possible while demonstrating responsible management of funds and equipment. Adoption of mitigation measures discussed in this section will be considered at the time of the decision whether to proceed with the proposed action or one of the alternatives. Measures suggested during the public review period will also be considered.

4.2 Land and Minerals

Potential adverse effects on land and minerals are related to borrow pit development, change in land status, permafrost degradation, and geohazards. With the implementation of sound planning, design, and construction practices, all such effects are expected to be minimal and limited in duration to the construction period. No adverse effects are expected during facility operations.

4.2.1 Development of Borrow Sources and Spoil Disposal Sites

The development of borrow sources for fill and cover materials could result in adverse effects on land in the project area. Depending on the site location and construction method, material requirements are estimated to range from 0.2 million to 15 million cubic yards each for the transmit and receive sites.

Impacts associated with the use of existing borrow sources and disposal sites include degradation of roads by heavy trucks and depletion of available resources. Where available gravel resources are low, gravel use for the ARS could limit the quantities available for general road maintenance and other uses in the vicinity. However, use of existing materials sites could generate revenues for private businesses or state agencies.

Developing new borrow sources and spoil disposal sites would result in minor land alterations through test site drilling and trenching, as well as constructing new trail or road access. Devel ng new gravel sources would require excavation and disturbance of up to 20 acres.

Impacts associated with borrow and disposal sites are likely to be greater in the Glennallen and Gulkana study areas because local, fine-grained soils are readily susceptible to erosion and alteration of the thermal regime. The quantities of gravel available in these areas are also relatively low; as a result, the potential for conflicts with other users is higher. Lesser impacts are expected at the Indian Creek and Paxson East study areas because bedrock is present at shallow depth and is less susceptible to erosion and thermal alteration. In addition, potential conflicts with other users are less likely because larger quantities of gravel are present in these areas. Few impacts are expected at the Tok study area because suitable borrow sites are likely to be located in or near the study area, and terrain conditions are favorable for construction and removal of gravel resources.

Before development of borrow sources for the ARS project, the Air Force would survey gravel resources in the project vicinity. Existing and abandoned pits would be evaluated first for the quantity and quality of gravel available. Discussions would be held with the Alaska Department of Transportation and other owners and users of existing pits to identify planned future uses of gravel. If it is determined that either the required amount of gravel is unavailable in existing pits or its acquisition for the ARS would significantly affect other planned uses, the Air Force would, if necessary, locate new gravel resources and obtain the required permits for developing new gravel pits before site preparation.

Borrow pits and spoil disposal areas would be operated in compliance with all applicable federal and state regulations. If gravel is to be extracted from floodplains, appropriate guidelines (e.g., U.S. Fish and Wildlife Service, 1980) would be consulted. Whenever feasible, excess material would be disposed of on upland sites and wetland areas would be avoided. As required, postconstruction impacts would be mitigated by reclamation through recontouring and revegetation of disturbed areas. The University of Alaska Plant Materials Center in Palmer, Alaska, would be contacted for site-specific information on revegetation techniques.

4.2.2 Change in Land Status

Project development would require approximately 1,300 acres at the transmit site and 1,200 acres at the receive site. Land acquisitions would comply with USAF Regulation 87-1 ("Acquisition of Real Property," dated December 1985). This regulation states that the Air Force may acquire real property, or the use rights to real property, by whatever methods satisfy its needs in the most economical manner and create the least impact on the civilian economy. The necessary rights may be acquired through purchase, lease, transfer or exchange agreements, donation of real property, or withdrawal from the public domain.

If existing land ownership at the sites is primarily federal, no adverse effects would be expected. However, land within all five study areas is owned primarily by the state, Native corporations, or private individuals; land use conflicts may or may not arise depending on site-specific land status and the owner's interests and desires. If disputes occur during the land acquisition process, the overall project schedule may be delayed. To minimize the likelihood that such problems will occur, negotiations with affected parties would be held early in project planning.

Site selection could also affect existing rights-of-way and leases. The Glennallen study area contains the Ewan Lake Trail and oil and gas leases. The Gulkana study area contains a power line right-of-way along with oil and gas leases. The Paxson East study area contains segments of the Trans-Alaska Pipeline, whereas the Tok study area contains rights-of-way for the Haines-Fairbanks Canadian Alaskan Oil (CANOL) Pipeline, the Alaska Railroad, the Alaska National Gas Transportation System (ANGTS) gas pipeline, and a power line. These rights-of-way will be evaluated further during the site selection process. If direct disturbance or rerouting of existing transmission or transportation facilities would significantly affect users of these facilities, they would be avoided, if possible.

4.2.3 Permafrost Degradation

Removing or disturbing vegetation over frost-susceptible soils could alter the thermal regime, which in turn could increase erosion, frost-jacking, and subsidence due to melting. All five study areas contain variable amounts of discontinuous permafrost with variable distributions. Sites within the Indian Creek and Paxson East study areas are the least likely to have conditions susceptible to permafrost degradation because of the presence of shallow bedrock and well-drained soils. The Tok study area, which contains both well-drained and ice-bonded soils, is moderately susceptible to these problems. Alteration of the thermal regime is most likely to occur at sites within the Glennallen and Gulkana study areas, both of which contain the thickest and most widespread permafrost conditions.

Mitigation of potential permafrost degradation effects involves both site-specific surveys to map and characterize frost-susceptible soils and the use of standard arctic design and construction practices. After the sites were selected, the Air Force would conduct a permafrost characterization program. The direct methods that may be used include frost probing, shallow soil borings, and drilling to obtain samples for temperature- and frost-susceptibility analyses. Indirect methods for mapping permafrost distribution include electromagnetics, contact and noncontact ground-resistivity surveys, and subsurface interface radar.

After site-specific permafrost conditions have been defined, the appropriate design and construction practices would be incorporated into the ARS project. For example, construction work in areas containing frost-susceptible soils would not be conducted until gravel or pilings had been installed. A number of other mitigating measures are available, including the use of insulating materials and the maintenance of vegetation as a natural insulating mat. With appropriate mitigation measures, permafrost degradation and its associated effects are expected to be minor and local.

4.2.4 Geohazards

Adverse impacts could result from facility construction in floodplains, seismically active areas, and areas of potentially high soil erosion. In site selection, active floodplain areas would be avoided. Using standard seismic design criteria, foundations and structures would be designed to withstand seismic loading. Standard arctic construction practices would be used to minimize soil erosion. Consequently, no significant effects from geohazards are expected.

4.3 Vegetation

Effects of project development on vegetation would be relatively minor and limited to (1) retardation of vegetation succession near access and perimeter roads, along power transmission lines, and in front of the antennas; and (2) total loss of vegetation in cleared and graded areas, including road beds, building sites, staging areas, borrow pits, and overburden disposal areas. Estimating the areal extent of the vegetation that would be kept from succeeding to more advanced stages is difficult because road lengths and sizes of vegetation control areas would not be known until sites were selected. All told, the project could affect up to 3,000 acres of vegetation in one manner or another.

4.3.1 Loss of Vegetation

From a regional perspective, effects of the ARS project on vegetation are expected to be minor. No unique species or vegetation communities are known for any of the study areas, and the worst-case loss of approximately 3,000 acres would not be significant relative to the vast acreages of similar vegetated land in the region. However,

some local effects could be experienced at some of the study areas, depending on the specific site location. Potential effects at each study area are discussed below.

Vegetation potentially affected at the Glennallen study area includes the range of community types found in low-lying forests of the region. If commercial white spruce stands were affected, they might be salvaged for commercial use as saw timber, depending on the quantity of wood involved. Alternatively, felled trees could be salvaged as fuel wood.

4.3.2 Wetlands

Wetlands are the most important vegetation type that could be adversely affected by the ARS project at any of the five study areas. Degradation of these resources would be avoided whenever feasible during site selection. Special attention would be paid to those wetlands that are sedge-dominated or are contiguous with fish-bearing lakes and streams. If dredging or filling of wetlands is unavoidable, application would be made for a U.S. Army Corps of Engineers Section 404 permit. Obtaining this permit requires public and technical review of the project, and the Corps would not issue the permit until it was satisfied that important wetland values are adequately protected. As part of the permit, special mitigation measures dealing with such matters as culvert placement and erosion control may be required. Consequently, no adverse impacts on wetlands are expected.

Wetlands are common and widespread in the Glennallen study area. Bog vegetation, including extensive black-spruce-dominated communities, is very common and is likely to be affected by the ARS project. Bog community types in this region of Alaska are often indicative of underlying permafrost, and unless appropriate care is taken to preserve the thermal regime, environmental damage could extend beyond that associated with the act of clearing. For example, if thermokarsting were initiated, the primary effects would be on surface hydrology (see Section 4.5); also, bog vegetation in affected areas would change, and aquatic emergents such as rushes and sedges would eventually become dominant. The use of standard arctic construction practices would minimize the potential for such thermokarsting effects.

The Gulkana study area contains relatively dense growths of black spruce; as indicated above, this species may be indicative of bog conditions and/or permafrost terrain. Construction effects here would be similar to those described for the Glennallen study area.

The Indian Creek study area includes a broad range of vegetation associations. Bog vegetation is scarcer here than in either the Glennallen or Gulkana study area, but Indian Creek has fairly extensive areas of alpine vegetation. Black spruce types are the area's most common forest communities, and riparian areas along Indian Creek probably

support some white spruce and cottonwood associations. Viewed in a regional sense, none of the effects on vegetation at the Indian Creek study area would be significant. However, depending on the access route chosen, local changes in vegetation communities within the study area may occur. The most direct access route to the study area closely follows the course of Indian Creek. Road development here could significantly affect the study area's limited forested riparian vegetation; some of this vegetation may be destroyed and some may be set back to a younger seral stage. To mitigate such impacts, riparian zones would be avoided if possible during site selection and road design, and buffer strips would be retained along streams.

The Paxson East study area contains considerable wetlands but also contains vegetation characterized as a transition zone between forest and alpine types; scrub types (probably dominated by alder resin birch) are most common. Development here would not significantly affect any vegetation type because all types are common in the region.

The Tok study area includes wetlands and black spruce associations, although it may also have scattered, small stands of cottonwood and white spruce. Project development at Tok is expected to have no significant effects on the vegetation.

4.3.3 Loss of Threatened or Endangered Species

No indigenous Alaska plant species are listed as threatened or endangered. Of the 30 species considered as candidates for addition to the federal list, two species (*Montia bostockii* and *Taraxacum carneocoloratum*) might be found in the Indian Creek or Paxson East study area. Although the likelihood that either species is present in the project area is low, the Air Force would confer with the U.S. Fish and Wildlife Service about the possibility after sites were selected. If the potential for encountering either species were deemed to be unacceptably high, likely habitats would be surveyed before ground-disturbing activities were begun, and appropriate mitigation measures would be implemented as necessary.

4.4 Wildlife

Project activities that could alter wildlife populations in the study area include erection of large physical structures, development of transportation corridors, modifications of vegetation cover and habitat, creation of general noise and disturbance during construction, and alteration of aquatic habitat resulting from changes in stream sediment regimes.

4.4.1 Bird Collisions

The project may result in significant mortality for certain of the region's avian species and species groups as a result of collision with the transmit and receive antenna arrays. The species at greatest

risk for colliding with man-made structures are those that have high wing loads, such as ducks (Anderson, 1978; Meyer, 1978; Stout and Cornwall, 1976; Krapu, 1974), and those that have large bodies, such as swans (McKelvey, 1981; Weaver and St. Ores, 1974; Beer and Ogilvie, 1972; Eltringham, 1963; Banks, 1960), sandhill cranes (Thompson, 1978; Drewien, 1973), and eagles (Kroodsma, 1978). Although no data on other birds are available, it is reasonable to assume that other large-bodied raptors, such as ospreys, would be prone to such collisions. In some areas of Europe and North America, collisions with man-made structures, principally overhead wires, are believed to limit swan populations (Malcolm, 1974; Beer and Ogilvie, 1972). Kroodsma (1978) reports that approximately 10% of all known deaths of bald eagles in the 48 contiguous states resulted from collisions with overhead wires. In addition, certain species such as raptors have been electrocuted by bridging power transmission lines.

The principal type of structure involved in avian collisions is the overhead transmission line. Birds have difficulty perceiving a wire against a natural backdrop. Most avian collisions with structures take place under poor lighting conditions such as those that occur at twilight and during inclement weather. Low-lying ground fogs are an especially important factor contributing to collision mortality in North America (Anderson, 1978; Kroodsma, 1978; Meyer, 1978; Willard and Willard, 1978; Arend, 1970; Harrison, 1963; Banks, 1960; Quortrup and Schillinger, 1941). Structure orientation relative to flyways is another important variable in determining overall collision rates. Structures that cross special areas such as migration and breeding habitats or those that lie perpendicular to major flyways are particularly dangerous to birds (McKelvey, 1981; Anderson, 1978; Lee, 1978; Meyer, 1978; Stout and Cornwall, 1976; Beer and Ogilvie, 1972).

Because they are presumably more difficult to detect, smaller-diameter wires are more dangerous to flying birds than larger wires are (Meyer and Lee, 1979; Meyer, 1978; Thompson, 1978; Scott, Roberts, and Cadbury, 1972; Arend, 1970). Thompson (1978) stated that the collision hazard for any given wire appeared to be inversely proportional to its diameter.

The proposed antennas will superficially resemble a large metal fabric net. Relatively large-diameter beams will form the uprights and connecting structures; interspersed throughout will be a grid of smaller-diameter wire. Under most lighting conditions, birds should be able to see the complex of large beams. The ability of birds to see the back-screen wire mesh is not known. Adverse lighting and weather conditions could prevent birds from detecting the antenna array, and collision mortality could ensue. This effect could be significant at the Glennallen, Gulkana, and Tok study areas, as discussed below.

The Glennallen study area is located on a major bird migration corridor and is part of the breeding grounds for 20-25% of the world's trumpeter swan population. Project structures located in this area could conceivably limit the population growth of some species, especially trumpeter swans, but too little is known about avian movement patterns within the region to state this conclusion with certainty. Adverse environmental conditions that restrict flight are likely to occur sometimes when large numbers of birds are flying in the area. At such times, one could reasonably expect significant mortality to result, but it is not known whether this type of occurrence would be frequent enough to be population-limiting. The antenna arrays would certainly affect newly fledged trumpeter swans to a greater degree (on the average) than it would older cohorts. Newly fledged, heavy-bodied birds have very poor flight control and are accident prone as a result.

Other bird populations using the Glennallen study area would be affected by the structures as well, but probably not so noticeably as trumpeter swans. Because of the large, continent-wide populations of other species, as well as their broader breeding distribution in the region, they are unlikely to be significantly affected by the project. Selection of specific antenna sites away from known nesting areas would reduce bird collision risk in Glennallen. In general, this means that sites should not be chosen near Crosswind Lake.

Effects on birds at the Gulkana study area are expected to be less substantial than those at the Glennallen study area because trumpeter swan breeding density is lower in Gulkana. However, little is known about the flight pattern of trumpeter swan migrants that pass through the region going to and from breeding grounds elsewhere in Alaska. If the antenna site were located directly on the migration path, the overall effects on swans might be equal to or even greater than those anticipated for the Glennallen study area.

Project effects on birds that use the Tok study area could be quite significant at times. The antenna arrays would lie within the Tanana River valley, one of the principal bird migration avenues of Alaska. Approximately 200,000 sandhill cranes, hundreds of thousands of ducks of several species, and thousands of whistling swans pass through the study area each spring and fall. Because the area is used so extensively by species prone to collisions with man-made structures, mortality could be significant. As noted for the Glennallen and Gulkana study areas, collision rates probably would be highest during periods of inclement weather. At Tok during periods of fog, flocks that normally fly at higher altitude descend to follow the river just above ground level. Antennas near these locations would have significantly higher likelihood of causing collisions. Relatively few of the bird types listed above seem to breed near the Tok study area; thus, potential effects on young birds would be smaller at Tok than at either the Glennallen or the Gulkana study area. The Tok area does not have a significant number of

trumpeter swans, but it is an important nesting habitat for bald eagles and ospreys. As noted previously, these large-bodied raptors may also be vulnerable to collisions with project structures.

The Indian Creek study area is located at a relatively high elevation on the flanks of the Copper River lowlands, and it is probably removed from the migration routes of most birds. Antennas located there would probably have far less effect on bird populations than those expected for the Glennallen, Gulkana, or Tok study areas. Collision rates would probably be highest in winter, and most collisions would involve ptarmigan and, possibly, snow buntings. These birds travel in dense flocks in winter as they move between alpine and lower habitats in response to changing environmental conditions.

Project effects on birds at the Paxson East study area would probably be similar to those anticipated for the Indian Creek study area. The Paxson East study area is at a relatively high elevation and is located on the flanks of the Gulkana River flyway.

4.4.1.1 Bird Collision Avoidance

There are three general ways to minimize impacts due to collisions of birds with the radar antennas: site selection, modifications to the radar structure, and modifications to the environment. The selection of particular mitigation measures will depend on the study areas selected and the magnitude of potential impacts. Postconstruction monitoring could determine the effectiveness of techniques implemented to reduce bird collisions. Based on the results of such monitoring, the mitigation measures could be modified.

Among the factors to be considered and avoided, if possible, during site selection are areas of high bird use and areas subject to adverse climate. Areas of high bird use include open water bodies, wetlands, and nesting sites identified during prior surveys. Another approach to mitigation during site selection is the judicious alignment of the radar site in relation to local climate. Where feasible, the radar would be aligned parallel to the prevailing wind direction and outside any areas of frequent and heavy fog. Also, the radar antenna would be aligned, if possible not to lie across major local flyway routes such as rivers. Siting of the powerplant away from the antenna arrays would help reduce ice fog and reduce collisions.

Several actions can be taken to make the backscreen and towers more visible to birds and, therefore, to reduce the probability of a collision. Visibility of the backscreen may be enhanced by attaching highly visible objects such as tape or streamers. Flashing, dimly lit fluorescent lights have also been shown to reduce collisions of birds with tall structures at night. Other lighting schemes, especially in fog, can increase the risk of collision. Therefore the specific method of lighting needs to be based on careful analysis of existing literature.

Power lines will require precautions against bird collision and electrocution. Increasing the visibility of wire, proper design of the towers, and adequate wire separation could minimize these factors.

The environment can also be modified to reduce the likelihood of bird collisions. For example, the backscreen could be screened with trees or man-made structures that would force birds to fly over the backscreen. Also, bird habitats in the immediate site vicinity could be modified to redirect birds to other habitats.

4.4.2 Alteration of Aquatic Habitats

All five study areas provide breeding and rearing habitats for anadromous species of fish, a group afforded special protection by the Alaska State Constitution. Generally, most of the available information concerns the few large clear-water tributaries in the region; consequently, less is known of the actual distribution of anadromous fish, the duration of their presence, or their relative abundance in the smaller water bodies of the study areas.

Four of the five anadromous species in the study areas rear their young for at least one year in freshwater habitats that are typically located near their natal redds. Sockeye salmon usually rear in lakes while king, coho, and chum salmon, as well as steelhead trout, normally remain in flowing waters. Low-lying bog areas with surficial hydrologic connections to streams often provide additional rearing habitat for the salmon species. Beaver often play a crucial role in bog hydrology by excavating deep channels that run between ponds and streams and do not freeze solid in winter. On occasion, these channels provide rearing habitat for salmon.

The principal adverse effects on anadromous fish could include sedimentation of spawning beds through erosion of disturbed land, compaction of spawning gravels by direct streambed activity, dewatering of overwinter rearing habitats through alteration of surface hydrology following thermokarsting or water withdrawal, blockage of access to streams through deposition of overburden or through improper installation of culverts, and channelization of stream courses to facilitate road construction. (Also see Section 4.5.)

In the Paxson East study area, construction of the access road along Fish Creek could cause siltation in Fish Creek and Summit Lake, and earthwork for the antenna site on the high plateau in the study area could cause siltation in Gunn Lakes and Gunn Creek just north of the study area. All of these waters are important for sockeye salmon. If these waters were disturbed by construction, it could cause important

losses to commercial, subsistence, and recreational fishing. Such disturbance can be avoided by siting the access road away from the creeks, proper erosion control, and revegetation procedures. Adverse effects are not expected at the Gulkana Hatchery on the Gulkana River downstream from the Paxson East study area if proper precautions are taken during construction.

Development in the Indian Creek study area may require construction of an access road parallel and adjacent to Indian Creek, a relatively significant anadromous-fish stream. Construction of an access road along the stream could substantially increase its sediment load to the detriment of anadromous spawning habitats. The relatively long access road that would be necessary would also increase the potential for improper culvert placement, and thus could further reduce available spawning or rearing habitat. However these potential adverse effects could be mitigated through implementation of an erosion control plan and use of culvert placement standards set by the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game.

Development in either the Glennallen or the Gulkana study area could induce thermokarsting, which could in turn affect local drainage patterns to the detriment of anadromous and resident fish. Rearing habitats might be destroyed, together with some spawning habitats in minor tributaries; however, the overall effect is expected to be minor.

Development in the Tok study area would have little effect on fish in the Tanana River. Erosion control should prove relatively easy in the broad floodplain, and any increase in sedimentation that resulted from the project would probably not produce noticeable effects because of the naturally high turbidity of the Tanana and Tok Rivers.

Aquatic-furbearer habitats could be negatively affected by loss and disruption of habitat if thermokarsting were initiated as a result of development. This is most likely to be a problem in the Glennallen and Gulkana study areas, where low-lying bogs occur in association with permafrost. To mitigate this potential effect, the insulating mat of vegetation would be retained to the extent that is feasible.

4.4.3 General Human Disturbance

Trumpeter swans are quick to abandon nests and dependent young if they are disturbed by man or his activities (Hansen et al., 1971). Consequently, construction-related noise at either the Glennallen or the Gulkana study area could significantly reduce the reproductive success of these swans. After selection of antenna sites, potential measures to mitigate this impact would be evaluated. Mitigation measures to be considered include restrictions on aircraft overflight of active nests,

maintenance of a 1-mile buffer zone around occupied nests, and the prohibition of construction work in prime reproductive areas during the season of occupancy.

Increased human activity in the Paxson East and Indian Creek study areas could cause some brown bears to abandon timberline denning areas for the duration of the construction and operational period. Brown bears in Alaska often select den sites on south-facing slopes at or slightly above the timberline. However, because the project would affect a very small portion of the total habitat that exists in the region, its overall affect on bear denning should be minimal. Construction camp fencing and careful garbage control measures would help minimize problems with bears.

Increased human activity in the Indian Creek study area would probably result in the displacement of some bears from a regionally significant fish-foraging site, and in the destruction of other bears in defense of human life and property. Also, the continuous running of the power plants during the operational phase probably would displace bears for the duration of the project. However, overall regional effects are expected to be minor.

4.4.4 Alteration of Migration Patterns

Caribou movement patterns could be altered by the long, linear nature of the fenced antenna sites. Caribou are easily directed by such structures. Of the five study areas under consideration, only Tok is not regularly traversed by caribou. However, the overall effect is expected to be inconsequential because these redirections would be minor and should not lead to a reduction in caribou populations.

4.4.5 Increased Mortality

Indirect effects of the project on mammals include increased mortality of game and furbearers by sport and subsistence hunters as well as higher rates of collisions with vehicular traffic. Theoretically, higher harvest rates can be controlled through hunting regulations. Because increases in traffic are expected to be small, the effects of collisions on mammal populations are likely to be insignificant. Speed on the access roads can be controlled by posting speed limits. (See also Section 4.10.2.1.)

4.4.6 Effects on Endangered Species

The only endangered species likely to be found in the general project vicinity is the peregrine falcon. Although no nests are known to exist in any of the five study areas, falcons pass over or near these

areas during spring and fall migrations. The chance that they would collide with the radar antenna is probably small because falcons are agile flyers; however, this possibility would be investigated further after antenna sites have been identified. The Air Force initially would confer with the U.S. Fish and Wildlife Service and, if adverse effects may be significant, would initiate formal Section 7 consultation.

4.5 Water Resources

The following sections address the potential effects of project construction and operation on both surface water and groundwater resources. All effects are expected to be minor if standard design and engineering practices are followed.

4.5.1 Alteration of Surface Drainage Patterns

Surface drainage patterns could be adversely affected by construction in both permafrost and nonpermafrost areas. Permafrost degradation is a special concern in the lowland areas, which are more likely to be underlain by ice-rich lacustrine deposits. Substrates in this area are described as marginally frozen, in the range of -0.5°C to -1.5°C (Pewe and Reger, 1983); thus, they are particularly susceptible to damage when disturbed. Damage to the insulating layer of vegetation and organic material can lead to thawing, subsidence, and surface pooling. Surface pooling increases the heat conduction to the subsurface and thus induces additional thawing. As a result, thermokarst ponds can form and the local hydrological pattern can be altered.

All five study areas are in the general region of discontinuous permafrost and have the potential to be degraded; the lowland sites are particularly susceptible. The Glennallen study area appears to be the most susceptible to thaw impacts. In contrast with the alluvium of the other lowland study areas, underlying alluvium at the Tok study area may be largely ice-free, especially near the Tanana River. Extensive subsurface investigation of permafrost conditions would be conducted after specific sites have been selected (see Section 4.2.3). Alteration of the groundwater on the flat plateau in the Paxson East study area could affect Fish Lakes and Gunn Lakes.

Standard arctic design and engineering techniques have been developed to maintain the thermal integrity of the subsurface. Procedures for avoiding ground degradation and the resulting hydrologic impacts could include: (1) performing no cutting or grading on undisturbed ground; (2) removing no vegetation other than trees, to maintain the subsurface thermal regime; (3) paying careful attention to local drainage in road routing to avoid ponding of water; and (4) confining construction to winter. If appropriate construction practices are followed, adverse effects on surface water hydrology should be minimal.

In nonpermafrost areas, surface drainage could be altered by stripping vegetation and by cut-and-fill grading. Changes would be greater in more mountainous regions (and thus in the Paxson East study area), where precipitation and runoff are higher than in lowland areas. Removal of vegetation and organic cover in the mountainous areas could reduce overall water retention and lead to greater total basin runoff. Bank erosion and water quality impacts could also be affected if stream channels were directly altered. Mitigation measures include avoiding areas that contribute significantly to runoff (e.g., slopes in areas of high precipitation), avoiding the alteration of natural drainageways and stream channels, and maintaining as much vegetation as possible (or revegetating whenever possible) in disturbed areas.

4.5.2 Stream Siltation

Another important impact on surface water hydrology is stream siltation, which could result from gravel extraction and from road construction across streams. Borrow areas are likely to be located in unfrozen fluvial deposits in or near active river channels, where quarrying activities could increase the sediment loads of nearby rivers and damage groundwater recharge zones. Because borrow areas have not yet been designated, site-specific effects are unknown.

Several measures would be evaluated to minimize siltation effects on surface waters. These include selecting borrow sites away from active river channels and floodplains, restricting excavation to areas above the seasonal high water table, and revegetating the borrow site after excavation. In addition, removal of stream bank vegetation and rerouting of stream channels would be avoided; bridges instead of culverts would be employed as stream crossings whenever possible to minimize impacts on water quality.

4.5.3 Water Supply Development

Approximately 10,000 gpd of water would be required at each transmit and receive site during construction and operation. Water supplies would be developed from either groundwater aquifers or surface water sources, depending on water availability and quality. Because few wells have been drilled in or near the study areas, little is known about the quantity and quality of available groundwater. Several drilling attempts in the Glennallen area have resulted in dry wells, which suggest that groundwater resources may be limited in the Glennallen and Gulkana study areas. The shallow depths to bedrock at the Indian Creek and Paxson East study areas also indicate that groundwater sources may be limited. Supplies of groundwater at Tok are expected to be adequate.

If a groundwater source is developed, water withdrawal could affect existing users of the developed aquifer. These effects are likely to be insignificant because few wells exist in or near the study areas, and the project requires a relatively low rate of water production (approximately 7 gpm at the transmit site and 6 gpm at the receive site). If development of groundwater supplies is found to be a feasible option at either of the selected sites, other uses of the aquifer would be evaluated so that potential conflicts could be avoided.

For a lake to be a feasible source of supply, it must be large enough and deep enough to remain usable all year. The 10,000 gpd demand is approximately equivalent to 10 acre-feet of water per year, or an annual draw-down of 0.5 ft for a 20-acre lake (a circular lake roughly 0.2 mile in diameter). A withdrawal of this magnitude is unlikely to affect a 20-acre lake adversely.

After project sites have been identified, potential water supplies in the immediate site vicinity would be evaluated. Groundwater conditions would be assessed through a test well drilling and exploration program, and aquifer pump testing and water quality analyses would be conducted to determine the long-term use and capacity of wells and any possible impacts on existing users. As necessary, lakes and other potential surface water sources in the site vicinity would be evaluated for water supply and quality. Both environmental and socioeconomic effects would be considered in the selection of site water sources.

4.5.4 Wastewater Discharge

The discharge from the ARS of approximately 10,000 gpd of wastewater could increase surface runoff if the water is obtained from a groundwater source. Released water could also degrade permafrost, cause overland erosion in nonpermafrost areas, or contaminate groundwater aquifers. Potential adverse effects on surface water would be minimized by discharging wastewater as far as possible from streams, lakes, and shallow aquifers. Permafrost degradation and overland erosion would be avoided through the use of a leach field, evaporation lagoon, or direct channel discharge, depending on site conditions. No significant impacts on water quality are expected because applicable standards would be met.

4.5.5 Water Pollution from Petroleum Products and Other Contaminants

Water could be polluted by petroleum products and other contaminants as a result of road construction and facility operation. If diesel-fueled generators are used as a power source, petroleum could leak or spill from construction machinery, fuel storage tanks, and tanker trucks delivering diesel fuel. Other potential contaminants include calcium chloride, which may be used to suppress dust on roads.

The magnitude and duration of pollution effects would depend on geology, terrain, and the amount of runoff at each site. The Paxson East study area, which has sloping terrain and an annual runoff exceeding 20 inches, would be most susceptible to stream pollution. Drier lowland areas with poor surface drainage (t e Glennallen, Gulkana, and Tok study areas) would be least susceptible.

To mitigate potential adverse effects, only approved dust suppressants would be applied and their use near stream crossings would be restricted. Fuel tanks at both the transmitter and the receiver site would be located within a bermed area lined with an impermeable synthetic membrane and designed to hold 110% of the total tank storage volume. Also, the Air Force would prepare and implement a Spill Prevention Control and Countermeasure (SPCC) Plan for its fuel storage tanks. If a tank spilled, the maintenance crew would follow cleanup procedures specified in the SPCC Plan, and the spilled fuel would be prevented from reaching surface or groundwaters.

4.6 Air Quality

4.6.1 Power Plant

If no commercial power source was available, the Air Force would construct a 10-MW power plants at the transmit site. Estimated air pollutant emissions for this power plant are listed in Table 4-1.

Table 4-1

ARS TRANSMIT SITE POWER PLANT EMISSION RATES

Pollutant	Emissions[a] (tpy)
SO_2	240
NO_x	1,338
CO	124
TSP[b]	16
NMHC[c]	5.7

[a]Based on generaion of 10 MW of electricity using diesel-fueled generators.

[b]TSP = Total suspended particulates.

[c]NMHC = Nonmethane hydrocarbons.

Source: Henderson, 1986.

In arctic regions, the worst conditions for atmospheric pollution occur when winds are persistently calm and very strong temperature inversions exist near the surface (Bowling, 1986a). Such conditions, which are largely influenced by local topography, are most pronounced in open valleys with gentle slopes, particularly when the sun is less than 5^{o} above the horizon. Typically, higher elevations have more persistent winds that inhibit the formation of strong surface inversions. Also, daytime surface heating occurs whenever the sun elevation angle exceed 5^{o} (Bowling, 1986b).

The plume rise from an emission source is determined by its heat outputs, the ambient temperature, the wind speed, and the rate of change in atmospheric temperature with height. The Briggs (1969) equation for plume rise in a stable, stratified atmosphere during modest wind conditions indicates that the plume would rise 30 to 40 m above the top of the exhaust stack. Because closely spaced stacks produce a somewhat greater plume rise, four such stacks (for an assumed set of four 2,500-kW diesel-fueled generators) would produce a plume height of approximately 70 m.

For such a high plume rise, emissions would not mix vertically and would tend to stay aloft as arctic haze (Bowling, 1986b; Shaw, 1980). Periods of stronger winds would tend to disperse the plume, so that pollutant concentrations in either case would not be of concern. Under worst-case conditions, maximum ground-level concentrations would occur about 5 to 10 km downwind from the source (Turner, 1969). Table 4-2 lists the maximum concentrations for each pollutant under near-stagnant conditions. This table shows that only under the highly unlikely conditions of very low wind speeds and unchanged wind direction persisting for 24 hours could a violation of the SO_2 standard result (see Table 3-6).

4.6.2 Vehicles and Miscellaneous Engines

Air quality could be locally degraded during construction by emissions from internal combustion engines used in construction and by dust and noise created by construction equipment. Emissions from construction camp heaters, incinerators, and fuel sterage tanks could also add to the burden. During operation, degradation of local air quality could result from maintenance vehicles and solid waste incineration. The Air Force would comply with all applicable regulations concerning the operation of these engines.

Table 4-2

POLLUTANT CONCENTRATIONS UNDER
STAGNANT ATMOSPHERIC CONDITIONS

Emitted Pollutant	Maximum 1-Hour Concentration ($\mu g/m^3$)
SO_2	200
NO_x	1,120
CO	104
TSP[a]	12
NMHC[b]	4

Note: Assumes four 2,500-kW, closely spaced, diesel-fueled generators, and a wind speed of 0.5 m/s.

[a]TSP = Total suspended particulates.

[b]NMHC = Nonmethane hydrocarbons.

Source: Briggs, 1969.

Each ARS site would require an incinerator. This would be an oil-fired facility similar to those currently used at other Air Force installations in Alaska. The Air Force would comply with all applicable regulations.

Mobile pollutant sources during construction and operation would include both heavy equipment and worker vehicles. Emissions from heavy construction equipment would be small. The use of an on-site work camp during construction would reduce the potential traffic volume that would normally be generated by the peak work force of 200 people. Use of heavy equipment during construction would also create dust. Dust generation would be effectively mitigated by watering access roads and staging areas regularly.

During the operations phase, air pollutant would be generated by haul trucks and commuting vehicles, if any. Haul trucks would be used to supply each site throughout the year. A reliable supply of generator diesel fuel would require about three daily deliveries of 5,000 gallons, plus perhaps two more trips for food and supplies. Estimates of the daily emissions due to five round trips by haul trucks originating from either Fairbanks or Anchorage are listed in Table 4-3.

Table 4-3

MAXIMUM DAILY VEHICLE EMISSIONS, 1988

	Project								Nonproject				Total			
	Haul Trucks				ARS Vehicles				Other Vehicles				All Vehicles			
		Emissions[b] (kg/d)				Emissions[c,d] (kg/d)				Emissions[d,e] (kg/d)				Emissions (kg/d)		
	DVMT[a]	NO_x	CO	THC	DVMT	NO_x	CO	THC	DVMT	NO_x	CO	THC	DVMT	NO_x	CO	THC
Glennallen	1,500	27.0	30.5	12.9	1,500	5.2	69.0	7.6	50,000	172.0	2,302.5	256.0	53,000	204.2	2,402.0	276.5
Gulkana	1,650	29.7	33.5	14.2	1,500	5.2	69.0	7.6	24,000	82.6	1,105.2	122.8	27,150	117.5	1,207.7	144.6
Indian Ck.	2,000	36.0	40.6	17.2	1,500	5.2	69.0	7.6	8,000	27.5	3,684	40.9	11,500	68.7	478.0	65.7
Paxson	1,750	31.5	35.6	15.1	1,500	5.5	106.2	10.3	13,000	47.9	920.6	89.0	16,250	84.9	1,062.4	114.4
Tok	1,960	35.3	40.4	16.9	1,280	4.4	60.0	6.6	14,5000	49.8	667.7	74.2	17,740	89.5	788.1	97.7

[a]Daily vehicle miles traveled by haul trucks were calculated from Anchorage for the Glennallen, Gulkana, and Indian Creek study areas, and from Fairbanks for the Paxson East and Tok study areas.

[b]Average emission factors for heavy diesel trucks from model years 1978 to 1988 in use in 1988.

[c]Assuming 30 DVMT by each of 50 project vehicles (except Tok, for which 20 miles and 64 vehicles were assumed).

[d]Emission factors used were for conditions of 50% cold and 50% stabilized starts, 25°F average yearly temperature, and 35 mph average speed at low altitudes (at high altitude for Paxson East).

[e]Assuming 20 DVMT by each of the maximum number of local vehicles estimated by the Alaska Department of Transportation for 1988.

Sources: Calculated using data from Alaska Department of Transportation and Public Facilities (1983), and U.S. Environmental Protection Agency (1985).

Also shown in Table 4-3 are estimates of emissions from vehicles driven by operations personnel. Although living quarters would be built on each site, some personnel may choose to live off-site. A worst case of most employees commuting an average of 30 miles round trip was used to estimate vehicle emissions. Table 4-3 also lists estimates of the emissions from projected nonproject traffic (Alaska Department of Transportation and Public Facilities, 1983, that would travel the same commute routes.

Table 4-3 shows that the projected increase in vehicle miles traveled ranges from 6% at Glennallen to 44% at Indian Creek. In the Indian Creek area, existing nonproject traffic is very light (Alaska Department of Transportation and Public Facilities, 1983), and the background concentrations of all pollutants are well within the state standards (Coutts, 1986). Operational project traffic seems unlikely to cause significant threats to air quality in any of the study areas.

In high-latitude urban areas, winter air pollution episodes result from the persistence of intense nocturnal inversions during hours of maximum release of pollutants near the surface. Cold-start, CO automobile emissions and high energy demands during cold, dark winters contribute heavily to these episodes, especially in urban areas. Dispersion of these emissions is inhibited by the calm and stable winter atmosphere at high latitudes, especially in rural locales. The most effective mitigation measure is control of these emissions (Bowling, 1980).

The operations center proposed for Elmendorf AFB in Anchorage would require up to 315 people. The Anchorage urban area is currently a nonattainment area for CO--that is, CO concentrations exceed the ambient standard at least once per year. Therefore, the frequency of violations could increase if any vehicular sources of CO were added. The ARS work force would join other Elmendorf AFB personnel in participating on local control programs

4.6.3 Ice Fog

Water vapor created during the burning of fuels would contribute to episodes of ice fog during the appropriate atmospheric conditions. At temperatures above -20°C, the amount of water vapor generated is normally a small portion of the amount the air can hold at saturation. At -30°C, the amount of water in an exhaust plume is almost always sufficient to exceed water saturation during the cooling process. Polluted air can worsen the ice fog concentration by adding freezing nuclei to the atmosphere. Below -40°C, homogeneous nucleation of the droplets allows ice fog to form near natural water vapor sources such as hot springs. One potential consequence of ice fog is an increase in automobile accidents caused by low visibility (Bowling, 1986a).

Also, although undocumented, bird collisions with tall obstructions could increase during these periods. These episodes occur with greater frequency near the floor of large valleys, where nocturnal midwinter temperature inversions are strongest.

Incidents of heavy fog and ice fog would be expected more frequently in the valley basin areas of Gulkana, Glennallen, and Tok, where, on average, visibilities less than one-quarter mile occur only 18 times a year (National Climatic Center, 1984). One potential mitigating measure would be to locate the power plants at a higher elevation than the antenna site. The ice fog produced by the power plant would then originate and, under stagnant conditions, remain at a sufficient height to minimize additional fog at the antenna site and surrounding access roads (Bowling, 1986b). Another strategy would be to site the plant so that a ridge prevented any ice fog that was created from drifting into working or traveling zones. In any case, the Air Force would comply with all applicable requirements regarding fuel-burning operations and the reduction of water emissions in areas of potential ice fog.

4.7 Population

4.7.1 Copper River Valley, Alaska Range, and Tanana Valley Regions

The change in regional population (and other socioeconomic impacts considered in Sections 4.8 to 4.10) caused during the operation of the ARS would depend on the sites chosen, the sources of civilian employees, whether families accompany military personnel, and policies regarding workshifts and transportation to remote locations.

The impacts would be most widely dispersed if one site is in the Copper River valley/Alaska Range regions and the other is in the Tanana valley. If both sites are placed in the Copper River valley/Alaska Range regions, the impacts would be greatest on Glennallen, Copper Center, and Gulkana.

The number of new families that moved into the rural communities would depend on what portion of the civilian employees were hired from outside the region, the Air Force's policy about bringing families to remote locations, and the number of military personnel accompanied by dependents.

Finally, the residential patterns of employees would depend on the ARS work schedules--hours per shift and shift spacing--and on whether transportation would be provided by the civilian contractor or the Air Force.

For a reasonable range of assumptions regarding the number of military dependents and new civilian families that would move into the rural areas, the population change caused by one antenna site could range from 3% to 6% in the Copper River valley and 8% to 14% in the

Tanana valley. If both antennas were located at sites that affect Copper River valley communities, the population increase could be as much as 12% of the projected 1991 population for the Copper River valley.

Population impacts on specific communities would depend on the availability of housing and other facilities when operations begin. The scarcity of suitable housing and amenities near the Paxson East and Indian Creek study areas is expected to result in most employees living on the site or in the vicinity of Glennallen, Gulkana, and Copper Center.

4.7.2 Anchorage

Air Force employment resulting from the operations center at Elmendorf AFB is projected to be 315 persons. With dependents, the total population change would be approximately 550. This estimate is less than 0.2% of the estimated 1985 Anchorage population.

4.8 Economy

4.8.1 Employment

4.8.1.1 Copper River Valley, Alaska Range, and Tanana Valley Regions

Employment impacts would result from both construction and the operation of the ARS. During the construction phase, which would last more than 4 years, employment at each of the antenna sites could be as many as 200 persons during summer, but average employment is expected to be fewer than 100 persons.

The impact on regional employment would depend in part on the hiring practices of the contractor and subcontractors, which have not yet been selected. Although many experienced construction workers live in the Copper River valley and the Tanana valley, some workers with specialized skills who live outside these rural areas would probably be hired. The construction activity would increase employment in the Copper River valley and the Tanana valley significantly during summer peaks--possibly as much as 15% in the Copper River valley and 30% in the Tanana valley. The average employment increase is estimated at 7% in the Copper River valley and 20% in the Tanana valley.

Construction of the ARS would not be a new experience for the affected regions; rather, the ARS project would be similar to the Trans-Alaska Pipeline and the highway construction projects that have occurred periodically. Consequently, long-term residents have already experienced the dislocations that sometimes accompany an influx of workers and their attempts to find off-duty diversions.

During operation, employment is expected to be 70 at the transmit site and 65 at the receive site, representing roughly 5% of current employment in the Copper River valley and 12% in the Tanana valley.

Secondary employment effects are expected to be minimal because the rural regions have considerable excess capacity in the trade sectors to accommodate seasonal increases resulting from tourism. In addition, the variety of trade and service establishments in the rural communities is limited, and residents make periodic visits to Anchorage for major purchases. Assuming that 50% of the construction employment consists of local residents, the secondary employment is estimated to be between 30 and 35 persons. During operation, the secondary employment due to one antenna site is expected to be between 10 and 15 persons.

In general, the rural communities would benefit from the additional year-round employment opportunities. The extent to which underemployment of existing residents would be reduced depends on their skills and the hiring practices of the civilian contractor that is selected to operate the facilities.

4.8.1.2 Anchorage

Construction of the operations center at Elmendorf AFB near Anchorage is expected to require approximately 150 man-years over a period of 2 years. These estimates would imply average employment of 75 persons, but peak employment is estimated to be 200 persons. That number is less than 0.2% of current employment in Anchorage, which totals more than 115,000.

Purchases of construction materials and personal spending by construction workers would support trade and service employment in the Anchorage region. Whether this spending would result in additional employment would depend on economic conditions at the time. The current outlook is for little growth in the resource sector; hence, the employment effects of the ARS are expected to help maintain existing employment rather than to stimulate new growth.

During operation, the operations center would employ 315 people. Secondary employment effects in Anchorage could range from 250 to 350 jobs; however, as noted above, actual long-term impacts would depend on economic conditions in Anchorage during the operating phase and on the number of civilians hired from the local labor force. In any event, the maximum direct and indirect impact of the ARS on employment in the Anchorage region is unlikely to exceed 0.6% of current employment.

4.8.2 Income

4.8.2.1 Copper River Valley, Alaska Range, and Tanana Valley Regions

Construction costs are estimated to be $150 million for the transmit site (including the power plant) and $45 million for the

receive site. The distribution of these expenditures would depend on the contractor selected and on where the construction workers live; however, much of the spending is expected to flow to the urban areas of Anchorage and Valdez.

The spending arising from the construction of the sites would significantly increase local incomes. Local businesses would benefit from personal expenditures by resident and nonresident construction workers and from expenditures for materials and supplies. Estimating the magnitude of the local effects requires assumptions regarding the labor component of the project budget, local purchases of materials and supplies, the hiring of local construction workers, and the ability of the local economy to capture the secondary effects of local spending.

For the Copper River valley and the Tanana valley, the total direct and secondary income resulting from construction of the transmit site is estimated at $10 million to $12 million annually. This would increase personal income by roughly 15% to 20% in the Copper River valley and 35% to 40% in the Tanana valley.

For the receive site, income impacts during construction are estimated at $4 million to $5 million per year. This would be roughly 7% of current personal income in the Copper River valley.

If both antenna arrays were are constructed at sites that affect the Copper River valley, personal income could be increased by up to 30% for the two years of heaviest construction activity.

During operations, the Air Force payroll at each site is expected to be about $2 million. Secondary effects from this payroll would depend on the spending patterns of the personnel, but the total increase in income could be as much as 5% of current personal income levels in the Copper River valley, or 10% in the Tanana valley. Impacts resulting from operating expenditures could add 1% more to total personal income.

If both sites are located in the Copper River valley, income impacts could range between 7% and 10% of current personal income in the Copper River valley.

4.8.2.2 Anchorage

Total direct and secondary impacts during construction of the operations center would be approximately $10 million annually if all labor were hired locally and 40% of construction materials were purchased locally. This amount is a small fraction of current personal income in Anchorage.

During operations, the increase in personal income in the Anchorage area could range between $15 million and $20 million annually. This amount would not significantly affect total personal income in the Anchorage region.

4.8.3 Subsistence

Project effects on subsistence would depend largely on the exact location of the transmit and receive sites, as well as on the size of the construction and operation work forces. Primary subsistence concerns include loss of traditional land use areas, restrictions in access to such areas, and increased competition for the region's limited wild resources.

Effects on subsistence are related to project-induced changes in the region's wild resources as well as to changes in the regional economy. For example, if moose or caribou migration patterns were altered, subsistence hunters might need to travel farther to harvest them, and thus would expend additional time, money, and energy. If local residents were employed on the project, they could have less time available for pursuing subsistence activities. By contrast, additional employment for rural residents could lead to the pursuit of a wider range of subsistence activities and the use of more efficient equipment, such as powerboats and snow machines (Reckord, 1983a).

For projects on federal lands, further study of subsistence resources and use would be conducted under Section 810 of the Alaska National Interest Lands Conservation Act (16 U.S.C. §3120). Section 810 requires that federal decisions about the disposal of public lands take into account impacts on subsistence uses.

Access to subsistence resources could be impeded by fenced facilities. In addition to removing habitat, fenced facilities may direct some game away from traditional ranges to which subsistence users now have access. Use of caribou, in particular, could be affected because they migrate in large herds to winter ranges. On the other hand, subsistence users may benefit from some project facilities; for example, new roads could provide easier access to traditional resources and harvest areas. The project's roads could also facilitate access to wild resources by nonlocal subsistence users and recreationists who already hunt and fish along the region's transportation corridors. Decisions to mark such roads as open or closed would be made in consultation with local residents.

The project's fencing could serve to funnel certain animals, such as caribou, into more concentrated migration patterns that could lead to increased hunting by both subsistence and recreational users. In such cases, it may be necessary to restrict hunting in certain areas.

Subsistence users who could be affected by development in the Glennallen study area include residents from Glennallen, Gulkana, Gakona, Copper Center, Kenny Lake, and the Upper Tonsina, Lake Louise, and East Glenn Highway areas. Although the entire Glennallen study area is apparently used for various harvesting activities, development in the Crosswind Lake area would probably be the most disruptive because that area appears to be important to numerous subsistence harvesters of fish and wildlife.

Subsistence users who could be affected by development in the Gulkana study area include residents from Gakona, Copper Center, Chistochina, Gulkana, Kenny Lake, Chitina, Lake Louise, and the Upper Tonsina, Paxson-Sourdough, Matanuska Glacier/Sheep Mountain, and East Glenn Highway areas. Impacts on all but Gakona would probably be minimal, given that most users limit their activities within the study area to hunting, fishing, and gathering along the transportation corridors.

Subsistence users who could be affected by development in the Indian Creek study area include residents from Chistochina, Slana, Copper Center, Gakona, Glennallen, and the Nabesna and Upper Tonsina areas. Impacts on Slana and Chistochina would probably be greatest, given their proximity to this study area. Although harvesting of moose and furbearers appears to be conducted throughout the study area, the Indian Creek area itself appears to be the one most commonly used for subsistence pursuits.

Subsistence users who could be affected by development in the Paxson East study area include residents from the Paxson-Sourdough area, Gakona, and Glennallen. The impacts on harvesters from the Paxson-Sourdough area would probably be greatest, given their proximity to the study area and the variety of resources they harvest there.

Subsistence users who could be affected by development in the Tok study area include residents from Tanacross, Tok, Tetlin, and Northway. Impacts on Northway would probably be minimal, given its distance from the study area. It is more difficult to determine the impacts on the other communities, but the Tanana River corridor seems to be commonly used by all communities in their subsistence pursuits. Subsistence activities are central to these communities because wage employment opportunities are extremely limited. In addition, competition for wild resources would probably increase because some construction workers, permanent employees, and their dependents would participate in seasonal harvesting activities, particularly hunting, fishing, and berry gathering.

The state's subsistence law (A.S. 16.05.251) apportions subsistence hunting rights on the basis of rural residency rather than user need. Under this definition, all project employees might become eligible subsistence users, increasing competition for resources. If employees' dependents also live in the project area and conduct subsistence harvesting, the pressure on subsistence resources could approximately double. Because the land is generally poor in resources and the competition is already keen, this magnitude of additional harvest pressure could significantly affect present users.

4.8.4 Recreation

Construction and operation of the ARS is not expected to significantly reduce recreation opportunities for Alaskan residents or visitors to Alaska. Access to some land previously available for hunting may be lost. The construction workers would add to the general increase in resource use that occurs during the summer. However, the expected peak of 200 construction employees (including some local workers) would be a small fraction of the total visitor count, which is estimated at 600,000 in the Copper River valley.

Some effects of construction may impinge on recreation visitors in the rural areas. For example, construction workers may choose to occupy public campsites for temporary stays in rural areas. Although they would compete with recreational demand, their stays would be limited by restrictions that prevent long-term use of campgrounds. One possible positive effect would be an increase in the demand for guides by short-term construction employees.

During operation of the ARS, some fraction of the military and civilian employees of the sites are expected to hunt and fish in the regions of the Copper River valley, Alaska Range, and Tanana valley. The impact of this activity would depend on the number of nonresidents hired by the civilian contractor and the particular hunting and fishing activities they pursue. Relative to the total recreational activity in the rural regions, the impact of the permanent employees at the antenna sites on recreational resources would be small.

4.9 Housing

4.9.1 Copper River Valley, Alaska Range, and Tanana Valley Regoin

During construction, nonlocal workers may seek to rent housing in the rural communities. Even though much of it lacks complete plumbing and electrical features, it may be acceptable for a temporary stay.

During operation of the ARS, the impact on rural housing would depend on the number of nonlocal employees hired. Long-term adverse impacts are not expected because of the large amount of unoccupied housing that exists--more than 500 units in the Copper River valley--and the general availability of suitable housing sites. If demand for housing developed, new units presumably would be constructed or existing units would be remodeled and upgraded.

If 50% of the civilian contractor's employees were hired from outside the vicinity, the number of new households could range between 20 and 30 for each site. The maximum new demand would be less than 6% of occupied units in the Copper River valley and less than 4% of the 1980 count of year-round units.

The lack of housing units and electricity and the limited shopping facilities near the Paxson East and Indian Creek study areas may lead employees to commute from the Glennallen-Copper Center-Gakona region.

In the Tanana valley, the possible demand for 30 additional houses during the operation phase would exceed 10% of the total housing units occupied in 1980 in Tok and Tanacross. The total number of housing units within acceptable commuting distance of the Tok study area is difficult to estimate; however, in the broad area known as the Southeast Fairbanks Census Subarea, there are more than 2,000 year-round housing units.

The potentially significant impacts on the civilian housing stock could be mitigated by refurbishing DoD-owned quarters at the Tok pump station. In addition, the 4-year period required for construction of a site would allow ample time for the local construction and real estate market to adjust to expected increases in housing demands.

4.9.2 Anchorage

The work force for the operations center would total 315 military personnel and civilians. Although some military personnel are expected to occupy facilities for unaccompanied personnel on Elmendorf AFB, family housing is unlikely to be available. The large number of vacant rental units today indicates that new military and civilian personnel should have no trouble finding housing in the Anchorage area. A resurgence of economic growth in Alaska could change the housing outlook by the early 1990s, when ARS operation is planned; however, the maximum housing demand that could arise is less than 0.3% of the 1985 stock of housing units.

4.10 Community Facilities and Services

4.10.1 Education

4.10.1.1 Copper River Valley and Alaska Range Region

The Copper River School District has the physical facilities and faculty to accommodate additional students at the elementary and secondary levels. Some crowding could occur in Chistochina if an Indian Creek site is selected, but the shortage of housing reduces the likelihood that many new residents would choose to live in the region.

If approximately 20 to 30 new students accompanied workers at one site, the Copper River School District's enrollment would increase by less than 6%.

At Paxson, the school currently has five students and one teacher. Selection of a Paxson site could require additional faculty if employees of the civilian contractor chose to reside in the area and were able to find housing.

4.10.1.2 Tanana Valley Region

The schools of the Alaska Gateway School District could readily accommodate an increase of 20 to 30 students.

4.10.1.3 Anchorage

Personnel assigned to the operations center could add approximately 150 students to the enrollment of the Anchorage School District. This number is less than 10% of the enrollment decrease experienced in the 1985-86 school year (The Anchorage Times, 1986). Because the Anchorage district has an enrollment of more than 40,000 students, the students added during the operation phase of the ARS could be easily accommodated.

4.10.2 Transportation and Utility Services

4.10.2.1 Transportation

During construction, large trucks hauling materials are likely to cause periodic congestion on highways in the Copper River valley and Tanana valley. Any interference with traffic would be most noticeable during summer months when traffic counts reach their seasonal peaks.

During operation of the ARS, the transmit site would require regular deliveries of fuel oil for the power plant. An average of 25 trucks per week would be required to meet anticipated fuel requirements. This would increase average daily traffic on Copper River valley highways by 1% to 2%, depending on the site selected. This percentage is relatively small compared with the 100% increase in traffic flows projected between 1985 and 2005 (Alaska Department of Transportation and Public Facilities, 1985). Effects on vehicle traffic in Anchorage are expected to be negligible during both construction and operation phases.

The traffic volume arising from employees driving to work would depend on work schedules established by the civilian contractor, the fraction of employees choosing to live off-site, and on whether transport by van was adopted. Under worst-case assumptions (3 shifts per day, 1 person per car, 10 workers per shift), each antenna site would generate 60 trips per day. These would increase traffic by nearly 20% on the Tok Cutoff, but by less than 10% near Glennallen on the Glenn Highway.

The antenna arrays would present a risk to low-flying small planes. The risk could be minimized by informing pilots through normal aviation information channels [Notice to Airmen (NOTAMs)], marking the antenna locations on flight charts, and creating restriction zones and lighting.

The exclusionary nature of the ARS could affect ease of access to subsistence areas over winter and summer trail systems. In site selection, attempts would be made to avoid loss of access to and use of

river and creek channels. The overall level of impact would depend on the site selected and on detailed data concerning subsistence use. Mitigation measures could include siting facilities to avoid major trail routes or ensuring that the exclusionary area caused minimal deflection of routes.

4.10.2.2 <u>Water, Sewerage, and Solid Waste</u>

4.10.2.2.1 <u>Copper River, Alaska Range, and Tanana Valley Regions</u>

The number of new households associated with each antenna site could range between 20 and 30. This number is not likely to place a burden on water sources, sewage treatment, or solid waste disposal. The maximum landfill requirement for the households associated with a single antenna site is less than 1 acre over 30 years.

4.10.2.2.2 <u>Anchorage</u>

The additional households in the Anchorage area are unlikely to have a noticeable effect on the availability or quality of fresh water treatment, sewage treatment, or solid waste disposal in the Anchorage region.

4.10.3 <u>Electricity</u>

4.10.3.1 <u>Copper River Valley, Alaska Range, and Tanana Valley Regions</u>

The electricity demand arising from 20 to 30 additional households would not cause problems in communities served by the Copper Valley Electric Association or Alaska Power and Telephone. The two regional centers, Glennallen and Tok (and the nearby communities), have adequate generation capacity to accommodate additional households.

The communities of Chistochina, Paxson, Tetlin, and Mentasta Lake have very limited generation capacity and distribution systems that could be beneficially expanded. Because of the shortage of electricity and other amenities, it is unlikely that many ARS personnel would choose to reside in these communities. Should third-party power or excess Air Force electrical capacity be made available to local residents, increased electrification of the area could have a positive impact.

4.10.3.2 <u>Anchorage</u>

An additional 250 residential customers would not have a significant effect on utilities serving Anchorage.

4.11 Aesthetics

4.11.1 Methodology

The assessment of visual impacts is based on identifying changes to existing landscape features that would occur as a result of constructing and operating the ARS and evaluating the significance of these changes. The assessment method is the contrast rating process, a part of the standardized Visual Resource Management (VRM) System (U.S. Bureau of Land Management, 1978).

The contrast rating system numerically rates the degree of contrast between the proposed activity and the existing landscape. The resulting score is then compared with the suggested level of contrast for the VRM management class assigned as a result of a scenic quality and sensitivity evaluation. Mitigation actions are outlined for impacts that are considered significant.

The contrast rating process involves first separating a landscape into its major features (land, water, vegetation, and structures) and then each feature into its basic elements (form, line, color, texture). Each element is assigned a weighted value based on its significance in the landscape: form has the highest weight, 4; line is weighted as 3; color is weighted as 2; and texture is weighted as 1. The contrast rating compares the proposed activity with existing conditions, element by element, feature by feature, according to the degree of contrast (3 = strong, 2 = moderate, 1 = weak, 0 = none). The weighted value assigned to each element is then multiplied by the degree of contrast to arrive at the magnitude of visual impact.

The contrast rating identifies which landscape features and elements will be subject to visual impact from project development. Both short-term and long-term impacts are considered, and irretrievable commitments of visual resources are identified through this process.

A total contrast rating score for each landscape feature will fall into one of the following general categories:

- 0-10 points--contrast can be seen but does not attract attention.

- 11-20 points--attracts attention and begins to dominate the landscape scene.

- 21-30 points--landscape change demands attention and would not go unnoticed by the average observer.

This score is then compared with the VRM management class for the corresponding landscape to determine whether significant visual impacts would occur.

4.11.2 Impacts on Visual Resources

The requirement for a relatively flat, cleared land area and the strong vertical elements of the antenna at both the transmitting and receive sites in an otherwise natural setting would result in visual impacts in each of the study areas. The significance of these impacts would depend on the existing landscape features and scenic quality and on viewer sensitivity. At some study areas, scenic quality is low to moderate, and a site would be masked from public view by vegetation or natural topographic features or would be located 1 to 3 miles away from public-use areas (roads, trails, waterways). In these caes, impacts would not be significant. (At a 3-mile or greater distance, the antenna arrays would be extremely difficult for the human eye to distinguish.

The majority of landscape subunits within the study areas are gently rolling, open landscapes, with tundra-type vegetation (low brush, grasses, and clusters of spruce). Creeks, ponds, and drainages are seen in the foreground and middle ground, and scenic, snow-capped mountains form the distant background. Where they are visible, clearing and grading for the groundscreen and other leveled areas in these landscapes would result in high contrasts with existing form, color, and texture. The unnatural straight-line and vertical elements of the antennas and backscreens, access roads, and utility lines would contrast with the undulating contours of topographic relief and the meandering line of creeks, rivers, and drainages. These visual contrasts would be particularly apparent from aircraft or from elevated hiking trails along nearby mountain ridges.

Utility lines, antenna arrays, and support facilities located within view of public roads and recreation sites (hiking trails, waterways, camping areas, scenic overlooks) would result in visual contrasts with existing landscape features. These impacts would be particularly significant if their straight, angular, and vertical line and form intruded on scenic mountain vistas.

The impacts described above are generic to all study areas and would occur for the duration of the project. Temporary visual impacts associated with construction activities would also occur. These would include the presence of heavy construction equipment (dozers, graders, trucks, etc.), materials and staging areas, construction crews, dust, debris piles, and noise associated with construction activities. The significance of these temporary impacts would depend on the time of year (primary visitor season or not), the proximity to visitor use areas, and the duration of the activity.

The following subsections discuss the impacts on visual resources identified for each study area. These impacts are summarized in Table 4-4. Because the exact location of the proposed project facilities is not yet known, the analysis includes a worst-case situation in which sites are located within 1 mile of a public road.

Table 4-4

Summary of Impacts to Visual Resources

Study Area Location	Scenic Quality	Viewer Sensitivity	VRM Class	Maximum Element Contrast	Maximum Feature Contrast	Impact Significance	Notes
Glennallen	C	Low-high	III	32 Form	27 Line/vegetation	Not significant	Sparsely treed landscape provides natural screen from most viewing points (except aerial); existing Trans-Alaska Pipeline is linear feature west of the study area.
Gulkana	C	Low-high	III	32 Form	27 Line/vegetation	Not significant	Much of study area would be visible from Tok Cutoff or Richardson Highway. Spruce trees could effectively reduce extent of contrast; sites more than 1 mile from road would have minimal impacts.
Indian Creek	B	High (eastern sites	III	48 Form/land/veg.	27 Land/vegetation	Significant	Highly visible from Tok Cutoff. Strong visual contrasts. Antenna sites west of creek less sensitive because of distance from Tok Cutoff; new access road and utility lines would be visible from highway. Extensive fill and barrow required.
Paxson East	B	Low	III	48 Form/land	21 Land/vegetation	Not significant	Not visible, except by air.
Tok	C	High	IV	48 Form/veg.	27 Vegetation	Not significant	High sensitivity from along Alaska Highway; existing 700 ft LORAN antennas and support buildings dominate landscape. Trees would help screen project site from view.

4.11.2.1 Glennallen Study Area

A considerable amount of fill would be required for sites within this study area, resulting in landform modification of high contrast. Visual contrasts resulting from clearing, grading, and filling, and the construction of facilities would be noticeable from the Glenn Highway, if antenna sites were located within 1 to 3 miles of the highway. In some instances, intervening dense clusters of spruce would mask facilities and cleared site areas from public view, effectively reducing viewer sensitivity. Visual contrasts in color, texture, and line resulting from clearing of vegetation and from grading and filling would be most visible from low-flying aircraft. The sharp edge and angular shape of the cleared antenna site screen and the linear element of the perimeter and access road would contrast with the irregular line and pattern of natural landscape features.

Scenic quality in this study area is rated as Class C, and the VRM Class III has been assigned. Human modifications (Trans-Alaska Pipeline, utility lines, and radio tower) that have already been introduced to the natural landscape reduce the scenic quality and the sensitivity of visual contrasts. Visual contrasts resulting from the ARS could be mitigated through landscape design options and study area. Impacts would not be significant for sites located more than 1 mile from the Glenn Highway.

4.11.2.2 Gulkana Study Area

Impacts similar to those described above for the Glennallen study area would also apply to the Gulkana study area. Landform contrasts would be minor, however, because less fill would be required for this study area. Visual contrasts related to removal of vegetation would be similar to those described for Glenallen. Viewer sensitivity would be slightly higher than for Glennallen because a larger portion of the study area is within 1 to 3 miles of major roadways (Tok Cutoff and Richardson Highway) and the Gakona River. Buildings, utility lines, and antenna towers would be visible from roadway viewing points for sites within 1 mile of the road.

The use of earthen berms or intervening vegetation would reduce the degree of contrast in form and line for sites within this highly sensitive zone. Sites located beyond 1 mile from major roads would have little or no impact. Visual contrasts for the Gulkana study area can be effectively mitigated to meet VRM III objectives and are judged as not significant.

4.11.2.3 Indian Creek Study Area

In this study area, sites east of the creek would have the highest sensitivity. These locations would be within 1 mile of the Tok Cutoff, from which landscape contrasts would be highly visible and difficult to mitigate.

A considerable amount of fill could be required for facilities in this study area. Visual contrasts, such as visible scars and landform modifications, would result if borrow is taken from visible crests. The use of river ridges in the area and river gravels from the Copper and Chistochina Rivers would result in lower landform contrasts. Extensive tree cutting would also be necessary. These landscape modifications would be particularly sensitive (visible) for sites on the east side of Indian Creek. Significant visual contrasts in form, line, color, and texture would result from the construction activities at these sites. Additionally, the vertical form and straight line of the antenna arrays, backscreen, and utility lines and the geometric form of the buildings would contrast with existing landscape features and detract from the otherwise natural setting. Visual contrasts in the portion of the study area within 1 mile of the Tok Cutoff would be difficult to mitigate effectively and are assessed as significant.

The visual contrasts resulting from clearing and grading would be less significant for western sites because of their distance from the Tok Cutoff (more than 4 miles) and natural screening (vegetation and topographic relief). However, because no access road exists, new construction and the addition of a new element (line) visible from the Tok Cutoff would be necessary. A worst-case analysis for this study area assesses visual contrasts as significant.

4.11.2.4 <u>Paxson East Study Area</u>

Grading and borrow would result in visual contrasts with the irregular rolling ridges of the existing landscape. Strong contrasts in both line and color would result from clearing existing tundra vegetation (mosses, lichens, low brush) for the groundscreen. The angular form of support facilities and the vertical line and form of the arrays would contrast with the existing meandering lines of creeks and drainages and the contours of ridge lines.

The access road to sites within the study area might follow an existing jeep trail along the Fish Creek drainage. Because the antenna arrays and support facilities would be located 3 to 4 miles from the highway and would generally be masked from view by two intervening hills, the impacts on visual resources are not considered significant for this study area. The most sensitive viewing angle would be the view from aircraft flying over the site. The tops of the arrays could be visible from portions of the Gakona River; however, these contrasts are not considered significant.

4.11.2.5 <u>Tok Study Area</u>

Because the study area is relatively flat, minimal earthwork would be required. The area is assigned an interim VRM IV class because the existing LORAN station (four 700-ft towers) and support facilities dominate the landscape viewed from the Alaska Highway. The extensive

clearing required at this site would result in high contrasts in form, color, and texture. The cleared and graveled area for the access and perimeter roads would introduce a new element of line into the landscape and create moderate contrasts with existing features.

Visual contrasts at the Tok study area would be highly visible to motorists along the Alaska Highway, which traverses the study area. In the context of existing landscape modifications and opportunities to screen the project from view with existing vegetation, these impacts are not considered significant.

4.11.3 Mitigation

The following actions could reduce or eliminate significant visual contrasts:

- Site antenna arrays at least 1 mile from public roads, recreation areas, hiking trails, or rivers used for recreational boating. Use earthen berms or vegetative screens between the site and public viewing areas to screen contrasting features.

- Locate buildings out of view of public areas (roads, recreation sites) or behind vegetative screens or berms. Select exterior colors to minimize contrast, and avoid use of highly reflective surfaces.

- Minimize contrast of cleared areas by creating a natural, "feathered edge" that graduates from low or brushy plants at the outside edge to taller trees. Avoid straight-line cuts and minimize soil cover disturbance during clearing. Seed cleared, but unoccupied areas with lupine, vetch, or other flowering plants.

- Selectively clear trees and brush only where it is necessary for safety, operational requirements, or security.

- Avoid cuts along steep slopes visible from public roads. Contour and stabilize banks by revegetating cuts to reduce erosion and visual contrasts.

- Avoid placing utility lines where they are highly visibile, such as prominent ridges and heavily timbered areas where extensive clearing would be required. Join rights-of-way with other linear features, such as roads, utility lines, and pipelines, where feasible.

- Incorporate visual bends and breaks into right-of-way design.

4.12 Cultural Resources

Cultural resources studies focusing on the five study areas have been limited to literature review and identification of reported

resources. Because previous field surveys have not covered the majority of the lands under consideration, it is likely that the project would affect yet unidentified or unevaluated cultural resources.

The Air Force would follow procedures established under 36 CFR 800.4 to comply with the requirements of Section 106 of the National Historic Preservation Act of 1966 (as amended), Section 2(b) of Executive Order 11593, and applicable regulations and laws pertaining to the protection of Native heritage and religious sites. In consultation with the Alaska State Historic Preservation Officer, the Air Force would conduct studies to identify and evaluate National Register eligible properties within the affected areas (both direct and indirect) and would determine potential impacts on those properties. As needed, the Air Force would develop procedures to avoid or mitigate adverse effects on cultural resources and would request comment from the Advisory Council on Historic Preservation. The Air Force would also consult with local Alaskan Native groups and elders to identify properties of Native heritage and religious significance, determine project effects, and develop measures to protect important properties or mitigate adverse effects. As a result, no significant adverse effects on cultural resources are anticipated.

4.12.1 Direct Effects on Archeological and Historical Resources

The Alaska Office of History and Archeology has indicated a high probability that significant archeological and historical resources exist in the Glennallen, Gulkana, Indian Creek, and Paxson East study areas, with a somewhat lower probability that such resources exist in the Tok study area. Archeological and historical resources anticipated in the study areas are likely to consist of surface and subsurface materials as well as standing structures; all these would be readily affected by any modification of the ground, including clearing and grubbing activities, operation of construction equipment and all-terrain vehicles, placement of gravel and other fill materials, and construction of facility support systems. Consequently, archeological resources within those areas cleared of vegetation, including groundscreen and facilities construction areas, staging areas, road and fenceline corridors, and gravel borrow pits, could be directly affected by the project.

The following mitigation measures, in order of preference, would reduce or eliminate significant direct effects on cultural resources:

- Use of techniques that avoid the locations of, or contact with, significant resources (e.g., rerouting of roads or clearing of vegetation only above the snowpack level).

- Stabilization or preservation in place, including controlled placement of protective coverings (e.g., burial beneath gravel pads in areas such as groundscreens).

- Preconstruction recovery, analysis, evaluation, curation, and reporting of archeological resource data in areas to be disturbed, as outlined in Treatment of Archeological Properties: A Handbook (ACHP, 1980) (e.g., in areas of foundations, slabs-on-grade, support piles, below-grade utilidors, or site grading).

- Development of construction monitoring procedures, including employee training to ensure that resources discovered during construction are afforded timely and appropriate mitigation.

4.12.2 Alaskan Native Heritage and Religious Resources

Alaskan Native heritage values that could be adversely affected by project development include landforms, places, and prehistoric, historic, and cemetery sites. Because Native religious practices have not focused on the landscape, adverse effects on these religious values are not expected. Identification of these resources and mitigation measures would require consultation with local Alaskan Native representatives (e.g., Ahtna, Inc.; Copper River Native Association; Doyon, Ltd.; Tanana Chiefs Conference; Tetlin Native Corporation; Tanacross, Inc.; and elders) once project sites were identified. The probability of the presence of resources at the sites and the potential for impact cannot be determined until after sites have been selected.

Possible mitigation measures that could reduce or eliminate significant impacts include those noted above for archeological and historic resources, as well as the following:

- Oral interview studies documenting the nature and significance of heritage sites in and near the project area that may be physically or visually affected by project activities.

- Relocation of cemeteries in coordination with the affected local group.

- Development of agreements establishing a curatorial relationship with local Alaskan Native groups for materials removed as part of scientific data recovery.

4.12.3 Indirect Effects on Archeological and Historical Resources

Potential indirect effects on archeological and historical resources include vandalism, collection of materials, off-road vehicle damage, and operation of construction equipment outside the project areas. The magnitude of this effect would be directly related to the number of people migrating into the region. The level of impact for any given study area cannot be evaluated until site locations have been identified. However, the relatively small number of in-migrants required for project construction suggests that the indirect loss of scientific and heritage resource values would be minor. The following possible mitigation measures would be evaluated as necessary to minimize the potential for such effects.

- o Preferential local hiring of Alaskan Natives for project construction to reduce the number of in-migrants.

- o Development of an orientation program for contractor personnel explaining the legal penalties for collection of and damage to cultural resources on federal property.

- o Restriction of vehicle activity to construction areas.

4.12.4 Impacts on Cultural Resources at Elmendorf AFB

Potential impacts resulting from construction of the operations center at Elmendorf AFB fall under two categories: possible disturbance of archeological resources and visual impacts on buildings eligible for the National Register. For the current site, impacts on archeological resources are not anticipated. If the facility is sited as recommended in the Planning Assistance Team study (1985), however, archeological resources could be affected. The need for archeological studies would be evaluated in consultation with the Alaska State Historic Preservation Officer and the Base Historic Preservation Officer, and, if required, appropriate mitigation measures would be implemented as discussed in Section 4.12.1.

Although facilities at Elmendorf AFB have not been evaluated for inclusion in the National Register of Historic Places, the Base Historic Preservation Plan (Martin, 1986) identifies the Headquarters Building (5-800) as the most significant building on the base, and nomination procedures are anticipated. The ARS operations center is currently planned for a site near the Headquarters Building and may have a visual impact on the building's setting. Mitigation measures include architectural design that reduces the visual effect of the new building.

4.13 Electromagnetic Interference and Hazard Effects

4.13.1 Radiofrequency Radiation

The direct impacts of the ARS on the environment depend primarily on the magnitude, nature, and distribution of the RFR. A detailed description of the OTH-B radar is given in Appendix A, and a comprehensive technical description of its RFR is presented in Appendix B. Calculated values reported in this section are based on the field model described in Appendix B. Comparison of the measured and calculated values at the ERS in Maine, shows that the field model is well founded and conservative (see Table B-5).

This section describes the power densities of the RFR that would exist in the vicinity of the ARS transmit site. Even though the ground in the project region is quite conductive, the average power densities at ground level in front of the antenna arrays would decrease rather rapidly with distance. To avoid possible harm, an exclusion fence would be constructed to prevent humans and animals from approaching too close

to the antennas. In all cases, the highest values of average power density to which the general public would be exposed just outside the exclusion fence would be the maximum permissible values adopted by ANSI (ANSI, 1982).

4.13.1.1 RFR Fields

Time-averaged values of RFR are based on continuous radiation from both transmit arrays and include a factor of 0.14 to account for the fact that the beam would be pointed in any one direction only part of the time.* However, some specific potential effects related to electromagnetic interference depend on maximum values of power density and the detailed manner in which the frequency varies with time. For this reason, maximum values of power density and electric field intensity are also given. Appendix A includes details of representative modulation patterns.

A quantitative discussion of the intensity and possible effects of RFR requires use of a set of consistent units. Following common usage, all values of radiation intensity are expressed as power density in milliwatts per square centimeter (mW/cm^2); the unit used for area is square centimeters. Because land surveying is still based on English units, distances and dimensions are expressed in feet. Electric field intensities are given in volts per meter (V/m), the accepted units for this parameter. The symbol Z is used to identify the angle in degrees between the direction to a particular point and a line perpendicular to the applicable antenna array.

4.13.1.2 Identification of Sectors

Figure 4-1 shows the space subdivisions used for calculating RFR values in the vicinity of an OTH-B transmit array. The total RFR at any particular location is obtained by adding the separate contributions of all arrays at the transmit site. Actually, the electromagnetic radiation (EMR) from the two ARS arrays would not significantly overlap, and the total at any particular location would be essentially the same as the amount due to the major contributor. Values of average and maximum RFR were calculated for various locations in the three sectors shown in Figure 4-1. The results of these calculations are presented in Appendix B as Figures B-5 through B-10.

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*The beam points in a particular direction only 0.125 of the time. The larger factor (0.140) results from spillover of power from adjacent beams.

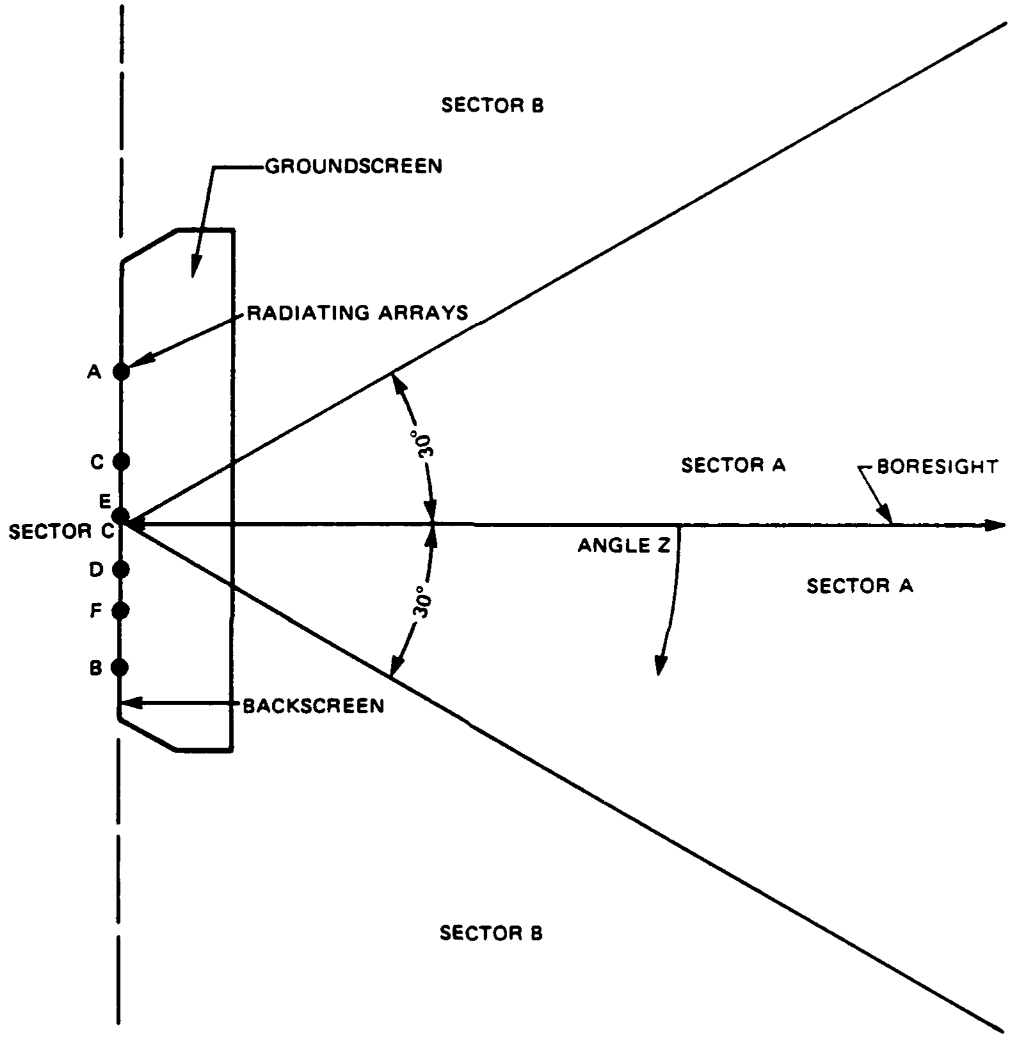


FIGURE 4-1 . SPACE SUBDIVISIONS USED FOR CALCULATION OF RFR (BAND E USED FOR EXAMPLE)

The highest values of RFR are found in sector A, which is identified with the main beam of whichever antenna array is transmitting. The radiation patterns of OTH-B antennas are complicated, and different relationships are needed to describe the behavior in different regions. One important distinction is between the near field, in which the power density is nearly independent of distance, and the far field, in which power density falls off sharply with increasing distance. For RFR at ground level, the most important parameter is the transition distance between these two fields, designated R_3 in Appendix B, at which the power density variation with distance changes from a $1/R^2$ behavior to one of $1/R^4$, where R is the distance from the array. Values of R_3 vary from 1,450 to 11,980 ft. The exclusion fence would be built so that the ground-level RFR outside the fence would be below the value recommended as safe by ANSI. To further simplify the procedure, RFR values were assumed to be independent of azimuth in sector A, which extends over a total azimuth range of 120° for the complete ARS system. This assumption overstates the expected values near the scan limits.

Sector B extends 60° beyond the scan limits; the only RFR in this sector is caused by sidelobes, which are at least 20 times weaker than the main beam. Moreover, in the complete system of two arrays, the scanning process is such that the stronger sidelobes extend beyond the scan limits only a small fraction of the time; this reduces the effective width of sector B to about 20°.

Sector C extends 180° directly behind the backscreen of each array. Values of RFR in this sector are at least 100 times lower than corresponding values in sector A. This permits a 10 to 1 reduction of the distance to the exclusion fence.

4.13.1.3 Power Densities at the Exclusion Fence

The exclusion fence is intended to prevent people and large animals from inadvertently approaching closer than about 4,000 ft from the antenna faces. Depending on details of the transmit site selected, it would generally be necessary to separate the antennas and to fence each array separately. However, the configuration and location of the exclusion fence would be chosen so that the power density outside the fence would be below the ANSI standard.

Just outside an exclusion fence 4,000 ft from an OTH-B array, the power density would not exceed 0.02 mW/cm^2. This is the highest level of RFR to which the general public would be exposed. This ground-level estimate neglects any attenuation that might result from trees or underbrush. For comparison, the most recent average values recommended by ANSI for nonoccupational, occupational, or chronic exposure to RFR in this frequency range vary from 1.15 to 36 mW/cm^2 for a frequency range from 28 to 5 MHz. The expected values are thus well below those permitted by the ANSI standard.

4.13.2 Electromagnetic Environment

4.13.2.1 The Addition to the Environment Near the Transmit Site

Operation of the ARS would change the electromagnetic environment over the frequency bands of its operation (and their harmonic frequencies) within the physical space its energy reaches. (This section on the electromagnetic environment is drawn from Appendix C, which contains a detailed analysis of the change.) This change can be described as an addition of electromagnetic energy to the electromagnetic environment, and assessed in terms of how the change may affect other systems and thus become perceptible to those using the systems. In this section, the addition to the environment is described; possible effects on systems are described in the following section.

Civilian use of the radio spectrum is under the control of the Federal Communications Commission (FCC); government use is under the control of the National Telecommunications and Information Administration (NTIA), formerly the Office of Telecommunications Policy (OTP). Because the OTH-B radar is a military system, a detailed application for spectrum support has been made through Air Force channels to the Interdepartment Radio Advisory Committee (IRAC) of the NTIA, which must authorize operation of the radar.

The OTH-B radar transmits in portions of the band from 5 to 28 MHz, which is within what is commonly called the high frequency (HF) band. An important characteristic of radio signals in this frequency band is that they can be reflected by layers of naturally occurring ionization at heights of 100 miles or more, so that the signal is reflected back to the ground at distances of thousands of miles. This is referred to as sky-wave propagation. The band as a whole is shared with various experimental radars, radio systems for air-to-ground and ship-to-shore communications, systems for standard time and frequency broadcasts, the Amateur Radio Service, Citizens Band radio, and others.

The specific portions of the HF band within which the OTH-B radar will transmit are those bands also occupied by transmitters of the Fixed Service and the Broadcast Service. The users of the Fixed Service operate fixed (i.e., not mobile), point-to-point links for the transmission of data or information from one part of the globe to another. Before the advent of communications satellites, the U.S. Armed Forces were major users of parts of the Fixed Service bands--operating large transmitting and receiving systems in Hawaii, California, and other locations worldwide. The Broadcast Service transmitters are also located throughout the world, broadcasting news, music, religious programs, and propaganda. They use the HF bands because the sky wave allows them to propagate their programming to areas at great distances from the transmitter, reaching audiences that they could not otherwise reach. Among these transmitters are those of Radio Moscow, the Voice of America, and the British Broadcasting Corporation (BBC); there are many others. The listeners are also, of course, spread throughout the world.

The OTH-B radar can operate on a large number of channels of various widths in the frequency range between 5 and 28 MHz, and it may or may not change frequency each time it switches its beam to illuminate a different portion of the surveillance region. Ionospheric conditions, which change with solar activity, time of day, and season of the year, dictate the particular range of frequencies that must be used to propagate the sky-wave signal to these regions. The radar operators monitor those frequencies to determine which ones appear to be unoccupied by other transmitters, and they then operate the radar on channels that appear to be unoccupied. From time to time, ionospheric conditions or operational considerations will require a frequency change; in the selection of the next operating frequency, the operators would place first priority on finding an acceptable channel in the Fixed bands before considering using a channel in the Broadcast bands. OTH-B radar operating procedures, which include detailed plans for interference avoidance, are being developed. Experience with the prototype ERS indicates that the OTH-B radar can be operated without interference to other authorized users of the HF radio spectrum.

Although the function of the OTH-B radar is to propagate a sky-wave signal, some of the energy will remain near the ground and propagate by what is termed a ground wave. (This is the normal daytime propagation mode for standard AM broadcast radio.) The ground-wave signal is attenuated relatively rapidly as it propagates away from the radar, and can be expected to fall to levels below the ambient radio noise at distances of 100 or 200 miles.

Not all of the radar's power enters the main beam. Much smaller concentrations of power appear in the antenna's sidelobes and back-lobes. The maximum power density in the sidelobes is no greater than 1/20, and that in the backlobes is no greater than 1/100, of the maximum power density of the main beam. Signals propagate from these minor lobes at a much lower power level than from the main beam.

The radar will emit signals on frequencies other than the intended one, but at a much lower power level. Great care is taken in the design of the radar system to minimize such signals because they are both a waste of transmitter power and a potential source of interference with other systems. Some of these unintended frequencies are integer multiples of the intended, or fundamental, frequency and are termed harmonics. Others are less clearly related to the fundamental, and are called spurious emissions. Harmonics and spurious signals will not generally be HF signals, and thus will not generally propagate by sky wave. Furthermore, their ground waves will be rapidly attenuated.

When a radar or other transmitter radiates a modulated signal in its desired frequency band, it also transmits some energy in the directly adjacent portions of the spectrum (out-of-band energy). That transmission is close enough in frequency to propagate along with the desired signal and to create the possibility of adjacent-channel interference.

(The strong possibility of adjacent-channel interference is the reason why adjacent television channels, such as 9 and 10, are not used in the same community.) The modulation of the OTH-B radar transmitters has been carefully designed to minimize the out-of-band energy; the transmitted signal has good spectral purity.

4.13.2.2 <u>The Effects of the OTH-B Radar on Systems</u>

The OTH-B radar's contribution to the electromagnetic environment could affect systems that use the same environment, as well as systems that are not intended to receive electromagnetic energy. Other users of the spectrum include TV, radio, and other radars. Systems or processes not intended to receive electromagnetic energy include cardiac pacemakers, electroexplosive devices (EEDs), and fuel handling. Calculations and predictions of interference summarized below are presented in Appendix C.

4.13.2.2.1 <u>Effects on Telecommunication, Radionavigation, and Radiolocation Systems</u>

4.13.2.2.1.1 <u>Services That Share the Bands with the OTH-B Radar</u>

Because the OTH-B radar will operate on frequencies that are also allocated to other services, mutual interference between the radar and the Fixed stations or interference with the listening activities of the international-broadcast audience is possible. It is to the advantage of the radar to avoid operating on frequencies that are already occupied because in such instances the radar could suffer interference as well as producing it. Policy will thus stipulate operation in the Fixed bands whenever possible, in preference to the Broadcast bands. The Fixed bands are thought to be sufficiently uncrowded that the radar will almost always be able to find unoccupied channels there. When it is in the Fixed band, the radar's transmitted spectrum is pure enough not to produce adjacent-channel interference for listeners in the Broadcast bands or for amateur broadcasters.

The method of selecting a radar operating frequency includes monitoring to determine whether any other potential user is currently occupying the frequency. However, because one of the characteristics of HF sky-wave propagation is that a signal can skip over a particular receiving location, monitoring at one place does not guarantee that a channel is unoccupied throughout the world. Thus, the radar could be operated on a frequency occupied by a Fixed transmitter; when that occurs, the radar could interfere with reception at the intended receiver. Both the intended signal and the radar's signal will typically propagate by sky wave. Because the single Fixed receiver might be anywhere on earth, no general way exists for determining whether the radar's signal will reach it. Even if the radar's signal does reach it, no general way exists for determining the power of the desired signal or the power of the radar's signal; thus, it is impossible to predict whether interference with reception of the desired

signal will occur. Operation of the ERS in this manner for approximately a year resulted in no reports of interference.

If the radar were inadvertently operated on a channel in use in the International Broadcast bands, interference with an unknown number of broadcast listeners at unknown locations throughout the world would be possible. Whether the interference would actually occur would depend on the relative strength of the broadcast and radar signals at each of the potentially interfered-with receivers, which is, in the general case, not predictable. However, the ERS operated with no reports of interference within the International Broadcast bands.

4.13.2.2.1.2 Services Adjacent to the OTH-B Radar Frequencies

The Amateur Radio Service is allocated four bands that are adjacent to Fixed bands in which the OTH-B radar will operate. These HF bands are used by amateur broadcasters for worldwide communications. The radar will not be operated close enough to the adjacent bands to produce interference there. Although amateurs were invited to provide the Air Force with reports of hearing the ERS signal, whether it was interfering with them or not, no such reports were ever received.

The Broadcast bands are also typically adjacent to some of the Fixed bands in which the radar is expected to generally operate. So, too, are various bands allocated to the Maritime Mobile and Aeronautical Mobile Services, and to standard time and frequency services. The radar will remain sufficiently far from the band edges that no adjacent-channel interference with users of these bands should occur.

4.13.2.2.1.3 Services Harmonically Related to the OTH-B Frequencies

The harmonics of the OTH-B signal are integer multiples of the desired, or fundamental, frequency. As such, they are typically at frequencies that will not propagate by sky wave to distant regions. Thus, any interference effects would be strictly local. Among the systems that might suffer interference from the radar's harmonics are television, land mobile radio, air-to-ground radio, and VHF (very high frequency) omnirange (VOR) air navigation beacons.

Although no in-depth study of the TV environment was made in the vicinity of the study areas, all the areas are beyond the service areas of the TV broadcast stations of Anchorage and Fairbanks. Thus, when residents have TV reception at all, it is achieved by means of broadcast translators, private earth stations, or the state's Entertainment Television Project.

A TV translator is usually sited on a favorably located hilltop above a community that cannot receive the same direct-broadcast TV signal that reaches the better-located translator. The translator changes the signal to another channel and rebroadcasts it at low power for local reception. Prediction of interference with such a translator

requires knowledge of its location relative to both the broadcast TV transmitter and the radar transmitter. That information is not yet available. If the radar were to affect the receiver portion of a translator, the interference would be transmitted to all of the translator's users. If such interference occurs, however, it will be at specific radar freuencies that can be determined and forbidden to the radar. Interference with individual TV receivers is discussed later. Interference to any privately owned earth stations is very unlikely.

Because of their populations, the Glennallen, Gulkana, and Tok areas are probably served by the Entertanment Television Project, in which two channels of TV programming are received by a local satellite earth station and then rebroadcast to the local community using low-power TV transmitters--typically on VHF TV channels. Considering the broad extent of this system in Alaska, project stations may exist near the more remote Paxson East and Indian Creek study areas. Interference with the receiving systems of the Project stations is not likely; any TV interference would be more likely to affect the individual TV receivers.

Measurements in Maine in the vicinity of the ERS indicated that at distances of 6 miles or more from the radar, the radar's harmonics that could potentially interfere with TV were much weaker than predicted, and were generally so weak that they were not detectable above the background radio noise. If interference resulting from the radar's operation on certain subharmonics of the TV signals were to occur in the study areas, the radar operators would be able to remedy the situation. They would determine those subharmonics, and the radar could be restricted from transmitting on them, just as certain other frequencies are already excluded.

Because low-band VHF land mobile radio operates at frequencies in the band between roughly 30 and 50 MHz, it might be susceptible to interference from OTH-B signal harmonics. Measurements at the ERS suggested that harmonic interference was unlikely at distances greater than about 3 or 4 miles, and a similar prediction applies for the ARS. Experience at the ERS includes a paper company that operated 50-MHz transceivers within several miles of the ERS without experiencing interference. In addition, as the radar was operating, a pair of high-band VHF handy-talkies were used without interference for communicating between the radar building and points about 2,000 ft directly in front of the radar. These units used a frequency of 154.6 MHz, however, which was not a harmonic of any of the radar frequencies used at that time. If the radar's harmonics do produce interference with any established land mobile systems in the area, the offending frequencies could be determined and their use by the radar prohibited. Other mitigating measures are also possible.

The VHF air-mobile communication frequencies in the 118- to 132-MHz band may be susceptible to fifth and higher harmonics. No complaints of interference with airborne communications occurred during ERS operation. However, if such problems occurred at the ARS site, the offending frequencies could be determined and excluded from use.

Radio-operated aids to air navigation include VOR and VORTAC (combined VOR and tactical air navigation [TACAN]) ground stations and the associated receiving equipment in aircraft. VORs transmit on frequencies in the 108- to 118-MHz band, and aircraft use the signal to determine their bearing in relation to the VOR.

Numerous ground-based radio aids to air navigation are located near the ARS study areas. They include VORTAC, nondirectional beacons, and VHF air-mobile communication stations. In addition, aircraft using the signals from these systems will pass close to the radar transmitter. The extent of the radar's effects on these systems is being investigated.

Measurements conducted in cooperation with the Federal Aviation Administration (FAA) at the ERS indicate that such interference may render a VOR unusable when aircraft are within about 30 miles of the front of the radar. This, again, is a potential harmonic problem that would result from operation of the radar only on certain frequencies. These frequencies could be determined and the radar excluded from using them. Alternatively, the FAA could change the frequencies of the VORs so that they would not be susceptible to interference from the radar.

4.13.2.2.1.4 Other Radio Services

Operation of the ARS is not expected to interfere with reception of broadcast radio beyond about 2 miles from the transmit site. The Air Force monitored AM and FM radio broadcasts on an automobile radio at a number of locations near the transmit site while the ERS was operating. It determined that no ERS interference with the AM or the FM broadcast bands occurred at distances greater than about 1 mile from the transmitting antenna array.

4.13.2.2.2 Effects on Pacemakers, Electroexplosive Devices, and Fuel Handling

A design susceptibility threshold of 200 V/m (the electric field equivalent to a pulse power density of 10 mW/cm^2) was suggested for cardiac pacemakers in a 1975 draft standard by the Association for the Advancement of Medical Instrumentation. A pacemaker is more likely to react to a pulsed field than to a continuous-wave (CW) field because it could confuse the pulses with the naturally occurring electrical signals that it is designed to sense.

The Air Force conducted measurements of pacemaker susceptibility to RF fields in the HF band in 1977, using a CW signal at 26 MHz. That signal is probably quite similar to the OTH-B linear FM-CW signal, which is essentially continuous (not pulsed). The Air Force tested 30 pacemakers, of which 17 were unaffected by fields as high as 850 V/m--the maximum field available from the test system. The susceptibility thresholds of the other pacemakers ranged from a high of 850 V/m to a

low of 230 V/m. These data suggest that modern pacemakers would be affected by OTH-B electromagnetic fields only if the fields considerably exceeded 200 V/m.

At ground level in front of the ARS, fields would fall below 200 V/m at a distance of about 1,300 ft from the center of the array; behind the array, fields would fall below 200 V/m at about 130 ft. The exclusion fence would be located in front of the arrays at such a distance that a person approaching the radar would not be subjected to fields exceeding about 25 V/m; therefore, the radar should present no hazard.

In the air in front of the radar, the fields would fall below 200 V/m at a slant range of about 1,300 ft or a horizontal distance of about 1,100 ft. Again, this region would be well within the exclusion fence, so that it is highly unlikely that a pacemaker owner would ever enter it. Although operation of the radar would not constitute a hazard to pacemaker owners, the Air Force would arrange with the FAA to publish an appropriate NOTAM to caution them.

Air Force Technical Manual T.O. 31Z-10-4, on electromagnetic radiation hazards, instructs that fuel-handling operations (e.g., fueling of aircraft) should not be undertaken in electromagnetic fields with pulse power density greater than 5,000 mW/cm^2. The fields in question are typically those of conventional radars, for which the pulse power is much greater than the average power. The OTH-B radar does not pulse like a typical radar; rather, it operates continuously. Its "pulse" power density and average power density are equivalent, providing that the average is taken over a time duration no greater than the time that the radar's beam is pointed in any given direction. The OTH-B power density, even in the near-field column, never exceeds about 258 mW/cm^2, which is a factor almost 20 lower than the maximum safe power density of 5,000 mW/cm^2. Thus, the ARS would not pose a hazard to existing or planned fuel-handling operations.

The Air Force also has a standard for determining safe separation distances between radars and areas where electroexplosive devices (EEDs) are stored, handled, or transported. Probably the most common EED is the electric blasting cap. At the recommended safe separation distances, EEDs are considered definitely safe; this conclusion does not imply that they are definitely unsafe at slightly shorter distances. In fact, the power density required to fire an EED is perhaps 100 times greater than the density used to define the safe separation distance.

The safe separation distances are determined by certain ground-wave power density thresholds, which, for a given transmitter power, are highly dependent on the electrical conductivity of the ground. For the ARS, predictions of power density were based on the high ground conductivity associated with thawed permafrost land, and they may overestimate

the actual power density by an as-yet-unknown amount. As a result, the safe separation distances discussed below are probably also greater than necessary by an unknown amount. The distances discussed below should be regarded as conservative figures. The eventual safe separation distances may be smaller.

The OTH-B radar would present no hazard to EEDs stored or being transported in metal containers at ground level at distances beyond about 1,300 ft from the array center. EEDs stored or being transported in nonmetal containers would definitely be safe at distances greater than roughly 2.3 miles in front of the radar or about 1,300 ft behind it (based on relatively high ground conductivity). If the ground conductivity were lower, the corresponding safe distances would be smaller. Only military aircraft are likely to be equipped with EEDs. Aircraft in flight, carrying or equipped with EEDs, would be beyond the hazardous area if they were more than about 1,300 ft from the front of the radar. They would be warned by a NOTAM. Thus, storage or transport of EEDs in metal containers would be safe anywhere outside a 4,000-ft exclusion fence; those in nonmetal containers would not be guaranteed safe unless removed to considerably greater distances.

The safe distance for handling EEDs in preparation for blasting would be determined for the selected transmit site based on ground conductivity measurements and actual power density measurements. Until that time, the following calculated distances would be used to define the safe separation distance. If the ground conductivity is as high as the assumed value, the distance beyond which EEDs may be safely handled in preparation for blasting is 4 miles. (The Institute of Makers of Explosives in its booklet on the safe handling of blasting caps recommends a 17-mile distance, but does not discuss ground conductivity; this is an extremely conservative distance and is probably based on the assumption of a very high ground conductivity.) At the ERS site, the calculated safe distance was less than 3 miles because of the somewhat lower conductivity of the soil in Maine. When the safe separation distances have been determined, the Air Force would notify surrounding land owners and state and local government offices to allow them to take appropriate actions.

4.14 Human Health Effects

4.14.1 Introduction

A critical review of the present state of knowledge regarding biological effects of RFR serves as the primary reference for the human health aspects of this assessment of ARS. This review is "Bioeffects of Radiofrequency Radiation: A Review Pertinent to Air Force Operations," by L. N. Heynick and P. Polson (1983). The review is being updated and expanded and when complete will be issued as "Critique of the Literature on Bioeffects of Radiofrequency Radiation: A Comprehensive Review Pertinent to Air Force Operations," by L. N. Heynick (in process). These reviews do not contain information about specific systems, but

include studies covering the frequency range of the OTH-B radar. The discussion and conclusions presented below regarding possible RFR bioeffects of the OTH-B radar were derived by considering the research results that are most significant scientifically and also pertinent to the operational characteristics of the OTH-B radar and to the RFR power densities outside the exclusion fence.

The organization of the subsections below, starting with "Problems of Risk Assessment" (4.14.1.2), parallels the corresponding sections of the 1983 review. By removing the prefix 4.14 from the subsection numbers, the corresponding section numbers in the review are obtained. The subsections below repeat appropriate parts of the review, (e.g., section summaries and overall conclusions), but bibliographic references have been removed and other minor changes have been made. This parallel arrangement permits use of this assessment as a complete document without the need to refer to the review unless the reader desires more detail or the reference citations.

4.14.1.1 Background

4.14.1.1.1 Definition of RFR

"RFR" is used as a generic term to include other terms commonly found in the published literature on bioeffects, such as electromagnetic radiation (EMR), nonionizing electromagnetic radiation (NIEMR), electromagnetic fields (EMF), radiofrequency electromagnetic (RFEM) fields, microwave radiation, microwave fields, and others. The center (carrier) frequencies of the OTH-B radar vary from 5 to 28 MHz, which are entirely within the 3- to 30-MHz high-frequency (HF) band. The waveform is of a frequency-modulated (FM) nature. Thus, even though the bioeffects literature encompasses studies from direct current (DC) to 300 GHz, with both unmodulated and modulated frequencies, the frequency range of primary interest here is approximately from 10 kHz to 30 GHz. Outside this range (e.g., at power line frequencies), the mechanisms of interaction are substantially different. As noted in Appendix B, the maximum anticipated revisit time for the OTH-B beam to return to a given direction is 80 seconds. This is much less than the 6 minutes averaging time designated in Section 4.14.1.3. Therefore, the following sections on health hazards use average power densities, but also consider pulse powers and modulation effects where so indicated by the literature.

4.14.1.1.2 The Problem

The basic issue is whether brief or continual exposure of people to the RFR produced by the ARS transmit antenna arrays is likely to affect their health adversely. Because the ARS receive antenna arrays do not emit RFR, they are not considered further in this section.

Exposure of humans to RFR from the ARS transmit arrays can occur under two circumstances. First, people may be airborne near the transmit site. In that event, they may be exposed to the main beam or sky wave. Second, persons outside the exclusion area may be exposed to the low-intensity RFR existing near the ground (ground wave).

(Possible exposure of individuals within the exclusion area is not considered because the Air Force will provide appropriate protective and control measures.)

4.14.1.1.2.1 Exposure While Airborne

Exposure of people in airplanes to the main beam is a possibility shared with many operational high-power radar systems, including experimental versions of the OTH-B system proposed for the ARS. However, no case of harm to humans from any such incidental exposure is known, and there is no reason to believe that the ARS situation would be different from that of other radar installations in this respect.

Regardless of the final ARS transmit site, the Air Force would request the FAA to issue a formal NOTAM to avoid the transmit site and an appropriate volume of airspace near it. Federal regulations governing general aviation require that airplanes maintain a minimum altitude of 500 ft over population centers and 1,000 ft over dense gatherings of people, such as in a stadium. In sparsely populated regions such as the present study areas, there are no altitude restrictions. Thus, it is possible that, even with a formal NOTAM, persons in small aircraft might occasionally fly past the transmit site and be exposed to the RFR for periods of about 1 minute or less. Calculations indicate that if an airplane flew at a constant altitude of 500 ft toward the antenna, the airplane would be exposed, at most, to a maximum instantaneous power density of about 3.5 mW/cm^2 under band F conditions. Similar calculations for an altitude of 1,000 ft yield a maximum instantaneous power density of about 0.9 mW/cm^2. A time-averaged power density greater than 1 mW/cm^2 would occur within about 1,500 ft of the antennas. However, the likelihood of aircraft flying so close is small, and the duration of exposure to such power densities would be brief. Further, a metal aircraft skin would provide considerable protective shielding. Consequently, it is most unlikely that people within the aircraft would suffer any health effects directly related to RFR exposure.

Humans can perceive pulsed RFR of appropriate characteristics as apparent sound. In animals, pulsed RFR may also produce other effects related to the pulse characteristics per se, such as changes in behavior and alterations in the blood-brain barrier. However, none of these effects would be of concern with regard to the ARS radar because it uses FM-CW rather than pulsed RFR.

Because of these considerations, this assessment gives no further attention to possible exposures of people in aircraft flying through the main beam of the ARS.

4.14.1.1.2.2 Near-Ground-Level Exposure

The location of the exclusion fence would ensure that the highest average power density at ground level immediately outside the exclusion area in any direction would not exceed the 1982 ANSI radiation protection

standard for the general population for the OTH-B frequency range. As distance from the transmit site increases, the ground-level power densities would decrease (see Appendix B) to even smaller values.

4.14.1.1.3 Data Base and Literature Selection

Under Air Force sponsorship, SRI International has compiled a data base of over 200 detailed reviews and analyses of research projects on RFR bioeffects published in various scientific journals and reports. Other sources for this review included the previously mentioned review of RFR bioeffects published by the Air Force, a comprehensive review by the U.S. Environmental Protection Agency (EPA), bibliographies in previous reviews of the literature, and several comprehensive bibliographies prepared by U.S. government personnel or by other organizations under government sponsorship.

Several criteria were used in selecting articles for this review. Complete, peer-reviewed papers published in scientific journals or in proceedings of scientific symposia were preferred. Initially, abstracts of presentations at scientific symposia were also selected if they included adequate details of the procedures and findings. However, full reports of such studies frequently failed to appear in the peer-reviewed literature, presumably because critical peer review revealed problems with the work. Peer review therefore became the most important criterion.

Other criteria included the date of publication (those articles that were most recent were preferred because of improvements in experimental methodology and in the technology of exposure and dose measurement), and the significance of the findings to human health (e.g., studies of human populations to find out whether the occurrence of specific effects is statistically higher in population samples exposed to RFR than in similar population samples not exposed, and experiments involving long-term exposure of animals). Other criteria included the relevance of an article to others on the same topic and possible relevance to concerns expressed by citizens' groups.

Most RFR bioeffects are frequency-dependent but not frequency-specific per se. Rather, the frequencies of the incident RFR (together with its average power density and polarization and the size, shape, and orientation of the biological entity) determine the rate of energy absorption and its internal distribution. Another criterion for selection was therefore the frequency involved. Rather than including only articles involving frequencies close to those of specific systems, selection extended to include those involving frequencies over the general range from 10 kHz to 30 GHz. (As noted earlier, the mechanisms of interaction become somewhat different above and below these approximate limits.) Resource constraints necessarily limited the number of articles selected. However, the articles selected are representative of the many reports on the biological effects of RFR appearing in the scientific literature.

4.14.1.1.4 Eastern European Bioeffects Literature

Probably the most controversial aspects of research on the biological effects of RFR are (1) the large discrepancies between results, at low levels of RFR, reported in the Eastern European literature and those obtained in Western countries such as the United States, and (2) the basic differences in philosophy between the two groups of countries in prescribing safety standards or guidelines for the protection of humans against possible hazards from RFR exposure.

From the end of World War II to about the late 1960s, few of the scientific reports on bioeffects research in the USSR (or other Eastern European countries) were amenable to critical review because they lacked essential information. In the early 1970s, starting with an international conference on RFR bioeffects held in Warsaw in 1973 under the joint sponsorship of the World Health Organization (WHO), the U.S. Department of Health, Education, and Welfare (HEW), and the Scientific Council to the Minister of Health and Social Welfare of Poland, international exchanges of information increased materially, and translations of Eastern European articles became easier to obtain. Because most of the Eastern European documents published before 1973 (and many since then) are merely abstracts that contain no details of the experimental method, number of subjects, or analytical approach used in the study, evaluation of them proved difficult. More recent Eastern European studies contain more detail. The review cites and analyzes some of them.

4.14.1.1.5 Present Climate and Context

4.14.1.1.5.1 Proliferation of RFR Emitters

Public use of RFR-generating devices and acceptance of their benefits have been growing almost exponentially over a number of years. Contributing to the expansion of RFR use in this country are public TV and radio broadcasting stations, ham radio transmitters, citizens-band radios, ground-level and satellite communication systems, civil and military aircraft navigation systems, airport traffic-control systems, medical diathermy units, defense tracking systems, weather radar systems, remote garage-door-opening devices, microwave ovens, and a variety of units for industrial heating and processing of materials.

The federal government regulates use of all of these devices, mainly through the FCC, restricting their operation to specific frequency bands and limiting the power levels that most devices may emit. Still, as the number of such devices increases, the background level of RFR is bound to increase as well, particularly in urban and industrial centers. The question continually arises whether this increasing level of RFR will be deleterious to human health.

Various agencies of the federal government have established programs to deal with the question of RFR effects on human health. The Air Force has taken an active role for more than 25 years in advancing the state

of knowledge of RFR bioeffects to ensure safety to the general population from its operations and to establish personnel-exposure regulations. The U.S. Army and Navy also maintain research programs on the biological effects of RFR. The EPA conducts programs to measure environmental levels of RFR and to assess in the laboratory the biological effects of RFR, and has published a comprehensive review of the literature. The Center for Devices and Radiological Health (formerly the Bureau of Radiological Health) has promulgated a performance standard for permissible microwave oven leakage. The National Institute for Occupational Safety and Health (NIOSH) is investigating the use of industrial RF and microwave devices and has published a draft of its recommended occupational exposure standards. The results of these programs indicate that the biological effects of RFR occur, with limited exceptions, only at average power densities exceeding about 1 mW/cm^2. Further, present maximum environmental levels in cities are in the range of 0.00001 to 0.005 mW/cm^2, with the occasional exception of regions in the immediate vicinity of broadcast towers, where environmental levels may range from less than 0.01 to more than 0.2 mW/cm^2.

In summary, the use and benefits of RFR devices for communications, radar, personal and home use, and in industry are widely accepted. On the other hand, the proliferation of the use of RFR devices, including various military radar and communications systems, raises concerns with many people that some as-yet-undefined hazardous biological effects may be associated with this proliferation. The EIS addresses such concerns with regard to the OTH-B radar.

4.14.1.1.5.2 Measurements of Environmental Levels of RFR in Selected U.S. Cities

The EPA has measured the environmental RFR field intensities at selected sites in various U.S. cities. In two reports, EPA investigators discuss the results for the 15 cities (a total of 486 sites) studied. The sites in each city were selected to permit estimation of cumulative fractions of the total population being exposed at or below various average power densities, based on the population figures for the 1970 census enumeration districts.

The frequency bands from 54 to 890 MHz were included in the analyses. Field strengths measured at each site were integrated over these bands and converted into equivalent average power densities. The site values in each city were then used with the population figures in the various census enumeration districts in a statistical model. The model was designed to estimate the population-weighted median exposure value for that city and to calculate other statistics of interest. These median values range from 0.000002 mW/cm^2 (for Chicago and San Francisco) to 0.000020 mW/cm^2 (for Portland, Oregon). The population-weighted median for all 15 cities is 0.0000048 mW/cm^2. The percentage of the population of each city exposed to less than 0.001 mW/cm^2

ranges from 97.2% (for Washington, D.C.) to 99.99% (for Houston, Texas), with a mean value for all 15 cities of 99.4%. The major contributions to these exposure values are from the FM-radio and TV broadcast stations.

The EPA also measured RFR levels at sites close to single or multiple RFR emitters. Typical locations included the bases of transmitter towers and the upper stories (including the roof) of tall buildings or hospital complexes close to transmitter towers. At the base of an FM tower on Mt. Wilson, California, for example, the fields ranged from 1 to 7 mW/cm^2, but such values are believed to be uncommon. Most measurements in tall buildings close to FM and TV transmitters yielded values well below 0.01 mW/cm^2. A few values, however, were close to or slightly greater than 0.2 mW/cm^2 (e.g., 0.23 mW/cm^2 on the roof of the Sears Building, Chicago).

4.14.1.2 Problems of Risk Assessment

Assessing risk to human health and setting standards to protect health are extremely complex problems. In addition to purely technical and scientific questions, there are problems involving philosophy, law, administration, and the feasibility of programs--problems that are still only vaguely recognized. It is clearly beyond the scope of this document to deal with those subjects in detail, but it is important that they be mentioned. Three aspects of risk assessment need to be considered: the scope of biological effects evaluated in setting standards, the overall approach to setting standards, and standards of protection from overexposure to RFR in the United States, the USSR, and other countries.

Alternative approaches to determining the acceptable degree of risk or undesirable effect can be illustrated by comparing occupational air pollution standards that prevailed until recently in the USSR and the United States. In the USSR, maximum allowable concentrations (MACs) for airborne noxious agents are set at a value that will not produce any deviation from normal in physiological parameters, or any disease in anyone exposed to the agent (occupational or general population). In the United States, threshold limit values (TLVs) for airborne noxious agents are set to ensure that nearly all workers can be exposed regularly during the working day without adverse effect. The differences stand out clearly: in the USSR, all biological effects are considered without regard to their medical significance or the possibility of human adaptation, and the values of MAC selected must, in principle, protect the most susceptible member of the population. In the United States, only harmful effects are considered, and protection is not extended to the most susceptible workers, except that a safety factor is generally included in the TLV so that an adverse reaction in an individual can be detected before serious medical consequences ensue.

Both approaches are predicated on the existence of a threshold concentration; that is, on a concentration below which no biological

effect will occur. In the absence of a true threshold, the extent of protection to give to the population can only be weighed against the cost and technical feasibility of providing that protection. Making such choices is the function of risk-benefit analysis in the assessment of environmental hazard.

The existence or nonexistence of thresholds has been debated at length, but much of the debate has been based on opinion rather than evidence. As a practical scientific matter, thresholds for noxious or deleterious effects must exist for at least some substances because many naturally occurring substances are essential to life at one concentration and highly toxic at higher concentrations. In this document, the possible existence of threshold levels for RFR effects is considered on a case-by-case basis, with due regard for the physiological mechanisms of effect.

4.14.1.3 Exposure Standards

The term "exposure standards" is generally applied to specifications or guidelines for permissible occupational or nonoccupational exposure of humans to electromagnetic fields. The standards are expressed as maximum power densities or field intensities in specific frequency ranges and for indicated exposure durations.

In 1982, ANSI Subcommittee C95.4 adopted a frequency-dependent standard for both occupational and general-public exposure to RFR to replace the ANSI Radiation Protection Guide of 10 mW/cm^2 published in 1974 (ANSI, 1982). The 1982 ANSI standard, shown in Table 4-5, was derived from analyses of a large number of recent representative experimental and theoretical results selected by a subcommittee of ANSI C95.4. It covers the frequency range from 300 kHz to 100 GHz and is based on a mean whole-body specific-absorption-rate (SAR) limit of 0.4 W/kg instead of a constant incident power density. SAR is defined as the rate at which radiofrequency electromagnetic energy is imparted to an element of mass of a biological body. The lowest limit, 1 mW/cm^2, is for the range from 30 to 300 MHz, within which RFR absorption by the human body as a resonant entity is highest. The value 0.4 W/kg includes a safety factor of 10, and the specified limits are not to be exceeded for exposures averaged over any 0.1-h period.

In the far field of an RFR source, the governing maximum values are the power densities shown in column 4 of Table 4-5, and the corresponding squares of the electric and magnetic field amplitudes (E^2 and H^2) in columns 2 and 3 are approximate "free-space" equivalents.

In the near field of an RFR source, the governing maxima are the values of E^2 and H^2, but these can be expressed in terms of corresponding power densities.

Table 4-5

1982 ANSI RADIOFREQUENCY RADIATION PROTECTION GUIDES

Frequency Range (MHz)	E^2 (V^2/m^2)	H^2 (A^2/m^2)	Power Density (mW/cm^2)
0.3 - 3	400,000	2.5	100
3 - 30	4,000 ($900/f^2$)	0.25 ($900/f^2$)	$900/f^2$
30 - 300	4,000	0.025	1.0
300 - 1.500	4,000 (f/300)	0.025 (f/300)	f/300
1,500 - 100,000	20,000	0.125	5.0

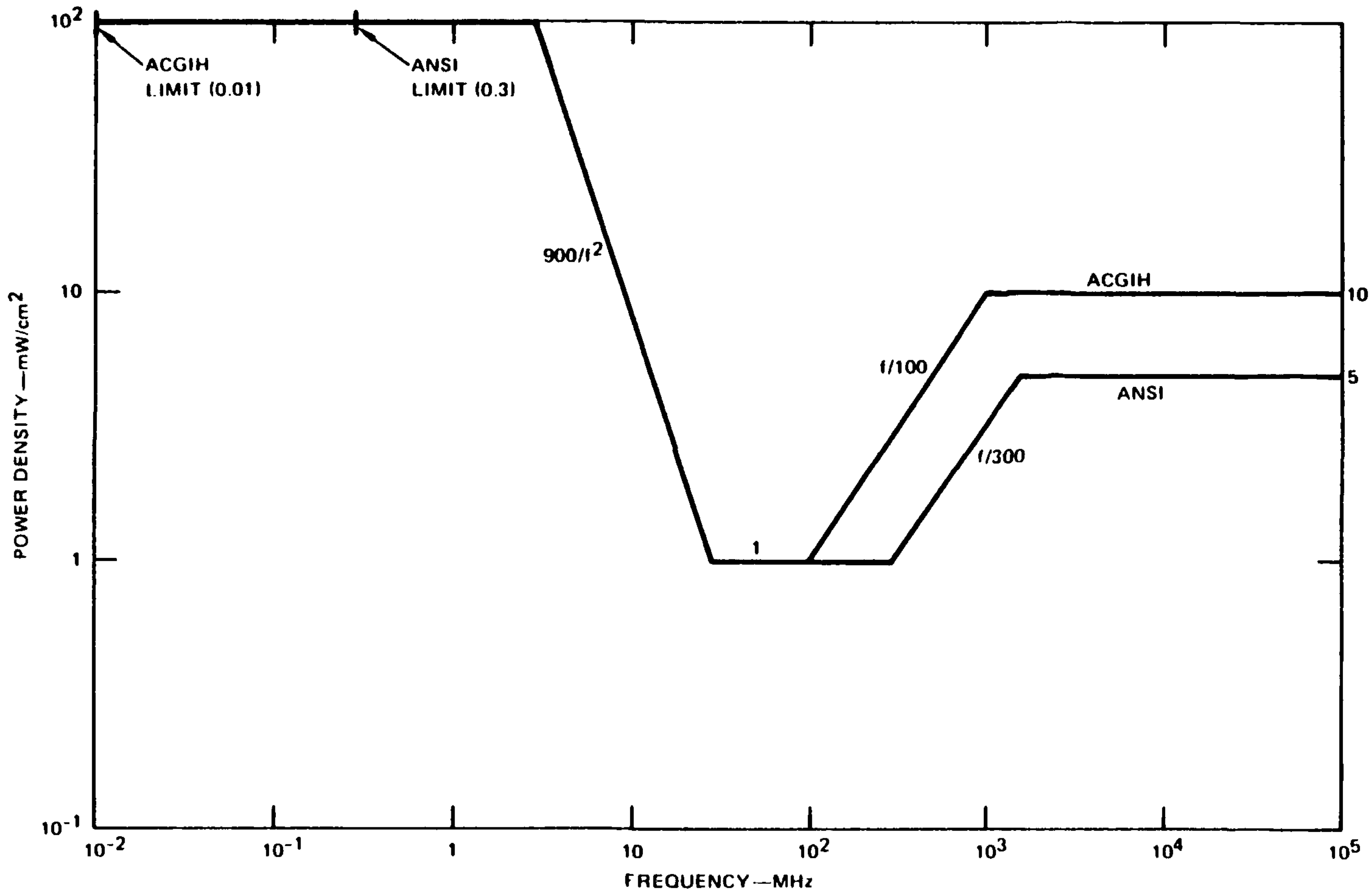
Note: f is the frequency in MHz.

Source: ANSI, 1982.

The ANSI power density limits for the OTH-B 5- to 28-MHz range are 36 to 1.15 mW/cm^2.

In 1983, the American Conference of Governmental Industrial Hygienists (ACGIH) published new threshold limit values for RFR. These are also based on 0.4 W/kg, but for occupational exposures only. The ACGIH threshold limit values are displayed graphically in Figure 4-2 for comparison with the ANSI values. The major difference is that the 1 mW/cm^2 value extends only from 30 to 100 MHz and rises from the latter with a slope f/100 to 10 mW/cm^2 at 1 GHz. This difference is based on the premise that children, who have higher whole-body resonant frequencies than adults, are unlikely to be occupationally exposed to RFR. Another difference is that the lower frequency limit for the ACGIH standard is at 10 kHz instead of 300 kHz.

The currently applicable Air Force permissible exposure limits (PELs) are given in AFOSH Standard 161-9. For exposures averaged over any 0.1-h period to frequencies between 10 MHz and 300 GHz, the PEL is 10 mW/cm^2, and from 10 MHz down to 10 kHz, the PEL is 50 mW/cm^2. For exposure within any 0.1-h period, the product of the power density and the exposure duration shall not exceed 3,600 $mW\text{-}s/cm^2$ for frequencies between 10 MHz and 300 GHz, or 18,000 $mW\text{-}s/cm^2$ for frequencies between 10 kHz and 10 MHz. This standard is being revised. Currently proposed PELs for exposure, during any 0.1-h period, of adults of normal size (55 in. or more tall) are the new ACGIH values, and the PELs for exposure of short humans (less than 55 in. tall) are the new



*Based on average SAR limit of 0.40 W/kg in exposed tissue.

SOURCES: ANSI, 1982; SRI International

FIGURE 4-2 ANSI AND ACGIH SAFETY GUIDES FOR WHOLE-BODY EXPOSURE OF HUMANS*

ANSI values, but extended down to the ACGIH lower frequency limit of 10 kHz. For the 5- to 28-MHz range, the new PELs for humans of both normal and small size are the same as the new ANSI values.

An exposure standard for the general (nonoccupational) population was proposed for internal consideration by the EPA in 1984. This standard was to be 10 times stricter than the 1982 ANSI guidelines, but was not issued because of conflicts within the agency, particularly concerning the inability to enumerate actual adverse health effects in the population resulting from RFR exposure. The matter is apparently still under review.

On 8 July 1983, the Executive Council of the International Radiation Protection Association (IRPA) approved interim guidelines on limits of exposure to radiofrequency electromagnetic fields in the frequency range from 100 kHz to 300 GHz (Mitchell, 1985). The International Nonionizing Radiation Committee of IRPA included participants from France, the Netherlands, Poland, Denmark, Germany, Great Britain, Australia, and the United States. These guidelines apply to RFR exposure of both occupational workers and the general-public. The general public values are given in Table 4-6. The basic limits of exposure for frequencies greater than 10 MHz are expressed in whole-body averaged SAR.

Table 4-6

IRPA GENERAL POPULATION RFR EXPOSURE LIMITS

Frequency (MHz)	E (V/m)	H (A/m)	Power Density (mW/cm^2)
0.1 - 1	87	0.23	2
1 - 10	$87/f^{1/2}$	$0.23/f^{1/2}$	2/f
10 - 400	27.5	0.073	0.2
400 - 2,000	$1,375f^{1/2}$	$0.0037f^{1/2}$	f/2,000
2,000 - 300,000	61	0.16	1

Source: Mitchell, 1985.

For practical purposes, derived limits of exposure are also expressed in average incident-power density. The derived limits appear to be conservative in the frequency range 10-30 MHz. The approach, to state the exposure limit in terms of whole-body SAR, represents a departure from current practices (i.e., most new standards express the permissible exposure levels in average incident-power density, even though they are based on limiting the whole-body SAR). For occupational

workers, the IRPA exposure limit for frequencies greater than 10 MHz is 0.4 W/kg when averaged over any 6 minutes and any 1 gram of tissue. For the general public, the IRPA exposure limit is 5 times lower (i.e., 0.08 W/kg when averaged over any 6 minutes and over the whole body, or 0.8 W/kg when averaged over any 6 minutes and any 1 gram of tissue).

These standards are based on the same assumption--that 4 W/kg is a reasonable threshold for adverse biological effects. Differences in the permissible incident-power densities as a function of frequency result from the degree of conservatism applied in each instance.

The IRPA general-population power density limits for the OTH-B 5- to 28-MHz range are 0.4 to 0.2 mW/cm^2.

Exposure limits in the USSR are considerably lower than those of Western countries, especially the limits for general-population exposure. Such standards are apparently based on their philosophy that exposure to power density levels that cause relatively small changes from normal mean values is potentially harmful. Until recently, the maximum level for 24-h exposure of the general population was 0.005 mW/cm^2, and the occupational standard was as summarized in Table 4-7. This table specifies higher maximum levels than those for the general population.

Table 4-7

MAXIMUM PERMISSIBLE LEVELS FOR OCCUPATIONAL EXPOSURE, USSR

Frequency (GHz)	Exposure Duration	Exposure Limit	Remarks
0.01 to 0.03	Working day	20 V/m	--
0.03 to 0.05	Working day	10 V/m 0.3 A/m	--
0.05 to 0.3	Working day	5 V/m 0.15 A/m	--
0.3 to 300	Working day	0.01 mW/cm^2	Stationary antennas
--	Working day	0.1 mW/cm^2	Rotating antennas
--	2 h	0.1 mW/cm^2	Stationary antennas
--	2 h	1 mW/cm^2	Rotating antennas
--	20 min	1 mW/cm^2	Stationary antennas

Source: Stuchly and Repacholi, 1978.

For example, for the 10- to 30-MHz range, an electric field intensity limit of 20 V/m is specified for exposures for a full working day. The free-space equivalent power density is 0.11 mW/cm^2. This standard provides no limit for frequencies below 10 MHz.

Recent U.S. visitors to the USSR have reported pending and/or adopted revisions to the above standards. For 24-h exposure of the general population, the maximum level has been increased from 0.005 to 0.010 mW/cm^2. The USSR also appears to be developing standards for specific types of RFR emitters. As examples, for a specific radar that emits 1-microsecond pulses of 10-cm (3-GHz) RFR at 3 pulses/s, the exposure limit is 0.015 mW/cm^2 (average power density), and for microwave ovens, the maximum value at a distance of 50 cm is 0.010 mW/cm^2. For occupational exposures in the frequency range from 0.3 to 30 GHz and exposures of 0.2 h or longer, the product of the average power density and the exposure duration should not exceed 0.2 mW-h/cm^2. Thus, the exposure limit for an 8-h working day has been increased from 0.010 to 0.025 mW/cm^2, the limit for 2-h exposure is 0.1 mW/cm^2 (no change), and the 1 mW/cm^2 limit is for exposures of less than 12 (instead of 20) min. Though not stated expressly, by implication these changes are applicable to RFR from stationary antennas; no information regarding rotating antennas was obtained. The limits for the frequency ranges 0.03 to 0.05 GHz and 0.05 to 0.3 GHz are unchanged. Again, there do not appear to be exposure limits for the range below 10 MHz.

The exposure limits in Poland and Czechoslovakia are higher than those of the USSR, but lower than those of the Western countries.

For general interest, the standards of Canada and Sweden and standards adopted or proposed by several state, county, and municipal governments in the United States are discussed in the review.

The average power density outside the exclusion fence around the ARS transmit array would be less than 0.02 mW/cm^2; that is, one-tenth the level specified by IRPA for continuous general-population exposure in this frequency band. The values at population centers near this transmit site are less than the new USSR standards for general population exposure.

4.14.1.4 Assessment of Scientific Information

In an assessment of the potential biological effects of RFR from a specific system, it is necessary to consider certain quantitative relationships among (1) the physical parameters of the RFR, such as frequency, power density, and polarization; (2) the mechanisms of absorption and distribution of energy within the biological organism; and (3) the resulting biological effects as measured by some functional or anatomic alteration. Like all scientific theory, the body of biophysical theory that links these three factors has been synthesized from a variety of experimental evidence. The theory is subject to refinement or revision as valid new evidence is accumulated that is

inconsistent with the theory. Nevertheless, it furnishes the context in which new experimental evidence is considered.

Obviously, the most directly applicable experimental evidence concerning possible bioeffects of any specific system would come from experiments in which humans were exposed to its specific frequency range and likely power density values. Furthermore, the best evidence would come from quantitative evaluation of a large number of biological endpoints. Such data, however, do not exist. The relatively small amount of data on human exposure to RFR have been derived primarily from epidemiologic studies conducted after exposure. However, such studies are rarely adequate because the numerical values of the exposure parameters for most epidemiologic studies are not known in detail, and the unexposed control group of people selected for comparison may differ significantly from the exposed population in factors other than exposure to RFR. Most available information is indirect because it is derived primarily from experiments with animals and requires at least some extrapolation of species, field characteristics, duration of exposure, and biological effects.

Regardless of the particular line of evidence being considered, certain concepts and constraints affect the interpretation. In particular, scientists disagree over whether an effect, especially one that is reversible or compensable, constitutes a hazard. Furthermore, only rarely is any particular study subjected to confirmation by the performance of an identical experiment by another investigator. More often, an analogous--but not identical--experiment is conducted with the objective of clarifying or expanding the results of the initial experiment. The second experiment ideally provides a better means of incorporating the findings into the theory that underlies the body of knowledge in a particular field of investigation, but it does not necessarily confirm the results of the first investigation.

Still another consideration is also important: scientific findings are probabilistic in nature, in that facts are known only to some level of probability for a given population; the applicability of those facts to a particular individual may be constrained. For example, the term "median effective dose" for a certain agent refers to the dose that will elicit the response characteristic of that agent in one-half of the exposed individuals. Before the dose is administered, however, one cannot predict whether any specific individual will respond, although the prediction that an individual will have a 50% chance of showing the response is valid. In effect, the probabilistic nature of scientific evidence means that no amount of scientific data can guarantee the absolute safety of any agent for any individual or group of individuals. Analysts disagree over whether the conventional scientific approach, whereby an investigator finds or fails to find a statistically significant (very low probability of chance occurrence) difference between experimental and control groups, is appropriate to considering potential hazards to humans. The scientist's statement that no statistically significant differences between the groups are discernible

is not equivalent to the absolute statement that no difference between the groups exists.

Conceivably, agents may have effects that are biologically real but so small in magnitude that the difference in mean response between experimental and control populations may not be discernible within the scattering of values for both populations if the sample sizes are small. Biological studies to detect such small differences and to show that they are statistically significant (to a prespecified probability that they are not due to chance) would require the use of large numbers of animals and, in some cases, long exposure times. The expenditures in time and money necessary to perform such studies may be so large that sponsoring institutions with limited budgets often decide that such studies are not cost-effective in terms of the sponsor's overall objectives. A frequent alternative is to predict effects at very low levels by extrapolation from findings at higher levels, on the basis of assumptions about the mathematical relationship between the level (or dose) of the agent and the degree of the effect. Such assumptions are open to challenge, however, and this approach may lead to disagreement over the possible existence of a threshold dose or dose rate below which the agent has no effects.

It must also be remembered that scientists have personal values, goals, and attitudes. It has been said that there is no such thing as an unbiased expert because becoming an accepted authority involves a personal commitment over a period of time that leads to emphasis of certain viewpoints. Thus, like probabilistic scientific findings, objectivity may well be characteristic of scientists as a group without necessarily being characteristic of any individual scientist. Personal bias can consciously or unconsciously affect how the experiment is designed, how the data are interpreted, and particularly how the results are applied to decision making. The last factor is especially important when the decision to be made is in an area outside the scientist's field of expertise.

Finally, scientific experiments are usually restricted to the evaluation of only one factor. In the real world, however, interactions are far more complex. The effect of combinations of factors is illustrated in the incidence of lung cancer in uranium miners, which is higher than in the general population, presumably as a result of the inhalation of radioactive material. The extent of the increased incidence in nonsmoking miners is marginal, but miners who smoke cigarettes have a much higher incidence of lung cancer than either nonsmoking miners or the general population. Thus, scientific evidence can supply only probabilistic information that is relatively narrow in its application to the real world.

4.14.1.5 Other Reviews

Representative, general reviews of the literature on RFR bioeffects, including several papers by Eastern European authors, are described in Section 1.6 of the review cited in Section 4.14.1.1.2, primarily as

background material. Although the conclusions of the authors of those reviews were examined carefully, it is important to note that the conclusions presented below regarding the consequences of human exposure to the RFR from the ARS were derived independently.

4.14.2 Interactions of RFR with Biological Entities

Interactions of electromagnetic fields with biological entities are often loosely characterized in the bioeffects literature as "thermal" or "nonthermal," a usage that has led to confusion and controversy. Therefore, it is appropriate at this point to introduce working definitions of these terms, with the recognition that the boundary between these types of interaction is not sharp.

The interaction of an agent (e.g., RFR) with an entity (biological or nonbiological) can be characterized as thermal if the energy absorbed by the entity is transformed at the absorption site into heat. Heat absorption, in turn, is defined in classical thermodynamics either as an increase in the mean random speed (or kinetic energy) of the molecules at the site (a local increase in temperature), or as an increase in the disorder or randomness of the molecular motion without an increase in mean random speed (a first-order phase change, such as the process involved in ice melting at 0°C), or both.

An entity can also absorb energy at specific discrete frequencies in the form of energy packets or "quanta," each of which has an energy proportional to one of the discrete frequencies. Although large numbers of molecules can be involved, quantum absorption is essentially a microscopic phenomenon in that the constituents and configurations of the various molecular species comprising the entity determine the specific frequencies or characteristic spectra at which such absorption can occur. The kinds of interactions involved are numerous and of varying degrees of complexity. They include alterations of molecular orientations and configurations that do not change the basic identities of the molecules, disruption of intermolecular or intramolecular bonds, and excitation of atoms or molecules to higher electron energy states (including ionization). Such interactions can be characterized as "short-range" processes.

It is theorized that cooperative interactions also occur among subunits of molecules within biological cells, in cell membranes, and in extracellular fluids. Cooperative interactions are often characterized as "long-range" because absorption of energy at one specific site in a structure (e.g., in a membrane or in a biological macromolecule) can affect a process elsewhere in the structure, or a function of the structure as a whole can be triggered by the release of energy stored in the structure, thereby producing biological amplification.

Conceptually, all such quantum interactions can be characterized as "nonthermal." However, if most of the energy thus absorbed is subsequently transformed locally into heat (as defined above), the distinction

between nonthermal and thermal is blurred. Pragmatically, therefore, characterization of an interaction of RFR with a biological entity as nonthermal requires that the interaction give rise to a frequency-specific effect that is experimentally distinguishable from heating effects caused by thermalization of the absorbed RFR energy.

4.14.2.1 Thermal Interactions and Specific Absorption Rates (SARs)

Consider now the effects of continuous-wave (CW) RFR on a human or an animal. The relative magnetic permeability of most organic constituents is about unity. Therefore, thermal interactions (as defined above) can be described in terms of the dielectric, electrically conductive, and thermal properties of the body organs, tissues, fluids, and so forth, as well as the characteristics of the RFR (frequency, power density, polarization). Measurements of these properties have been made for various mammalian tissues, blood, cellular suspensions, protein molecules, and bacteria over the frequency range from about 10 Hz to 20 GHz. In the subrange from about 300 MHz to about 10 GHz, the dielectric constant of such constituents as skin, muscle, and blood varies little with frequency, and the differences in values among such constituents are largely due to differences in tissue water content. In addition, electrical conductivity increases slowly with frequency in this subrange.

In the frequency range from 3 to 30 MHz (the frequency range of interest for this EIS), the dielectric constant of muscle varies from about 360 to about 110. The values for skin, blood, and other tissues with high water contents are comparable. The values for fat, bone, and other tissues with low water contents are about 10 times smaller and are sensitive to the amount of water the tissues contain.

Because the index of refraction of any material is related to its dielectric constant, RFR is reflected and refracted at boundaries between regions of differing dielectric properties, such as at the surface of a body (whether organic or inorganic), for the same physical reasons as those that apply to light at a glass-air interface. Thus, RFR at normal incidence to a relatively thick planar specimen is partially reflected at the surface, and the fraction of the power density entering the specimen suffers progressive attenuation with depth because of energy absorption. The concept of "penetration depth" is often used. For homogeneous specimens, the penetration depth is defined as the distance at which the electric field strength is about 37% of its value or, equivalently, the power density is about 14% of its value just within the surface. The numerical values of penetration depth depend on the electrical properties of the material.

Both the percentage of incident RFR that is reflected and the penetration depth vary inversely with frequency. In the 3- to 30-MHz range, about 95% to 85% of the incident power density is reflected at the air-skin interface, and the approximately 5% to 15% that enters the body is progressively attenuated with depth because of energy absorption

in the tissues. The penetration depths for skin, muscle, and other high-water tissues are about 91, 22, and 14 cm at 1, 10, and 27 MHz, respectively; the values are about 10 times greater for fat. Thus, although RFR at the frequencies in the OTH-B range is deeply penetrating, most of the incident power density is reflected at the surface of the body. At 100 kHz, the penetration depths of all constituents are quite large, but the reflection ratio is essentially 100%. On the other hand, at approximately 30 GHz and higher, penetration is largely confined to the outer layers of the skin.

In the literature on bioeffects of RFR, thermal energy absorption from an electromagnetic field is usually characterized by the SAR, which is defined as the rate of energy absorption per unit volume in a small volume at any locale within an entity, divided by the mean density of the constituents in that volume. SAR is expressed in units of W/kg or mW/g (1 mW/g = 1 W/kg). The numerical value of SAR in any small region within a biological entity depends on the characteristics of the incident field (power density, frequency, polarization), as well as on the properties of the entity and the location of the region. For biological entities that have complex shapes and internal distributions of constituents, spatial distributions of local SAR are difficult to determine by experiment or by calculation. Thus, the concept of "whole-body SAR," which represents the spatial average value for the body, is useful because it is a quantity that can be measured experimentally (e.g., by calorimetry) without information on the internal SAR distribution.

Many investigators have calculated or measured SAR and SAR distributions for relatively simple geometric models, including homogeneous and multilayered spheroids, ellipsoids, and cylinders that have weights and dimensions approximately representative of various species, including humans. An important result of this work is that the largest value of whole-body-averaged SAR is obtained when the longest dimension of each kind of model is parallel to the electric component of a linearly polarized plane-wave field (the "E" orientation) and when the wavelength of the incident RFR is about 2.5 times the longest dimension. The adjective "resonant" is often applied to the frequency corresponding to this wavelength. The resonant value of whole-body-averaged SAR for each model is also inversely dependent on the dimension perpendicular to the polarization direction (and propagation direction) of the field (i.e., the model has characteristics somewhat similar to those of a lossy dipole antenna in free space). Resonances would also occur for circularly polarized RFR. Such RFR can be resolved into two mutually perpendicular components, each having half the total power density. Therefore, an entity exposed to circularly polarized RFR would have lower resonant SAR values than it would have if exposed to linearly polarized RFR of the same total power density.

On the basis of prolate-spheroidal models (and linearly polarized RFR), the resonant frequency for an "average" man, approximately 5 ft 9 in. tall (1.75 m) and weighing about 154 lb (70 kg), insulated from

ground, is about 70 MHz; at this frequency the mean SAR is about 0.2 W/kg for 1 mW/cm^2 incident power density, or about 1/6 of his resting metabolic rate, or about 1/20 to 1/90 of his metabolic rate when performing exercise ranging from walking to sprinting. An alternative interpretation of this mean SAR value is that exposure to 1 mW/cm^2 for, say, 1 h would produce a mean temperature rise of about 0.2°C in the absence of any heat-removal mechanisms. At 30 MHz, the SAR is about 0.02 W/kg per mW/cm^2 for the E orientation. Therefore, exposure of the model man to the same power density for the same duration, but at 30 MHz, would produce a mean temperature rise of only about 0.02°C. However, actual temperature increases would be lower or even zero because physical heat-exchange mechanisms (conduction, convection, radiation) are always present, and for mammals (and other warm-blooded species) these mechanisms are controlled by thermoregulatory systems.

Similarly, the resonant frequency for an "average" woman (also insulated from ground), about 5 ft 3 in. tall is about 80 MHz, and her mean SAR is about the same as for the average man. The resonant frequency of a 10-year-old child is about 95 MHz; for a 5-year-old, about 110 MHz; and for a 1-year-old, about 190 MHz. The mean resonant SAR values for such children are about 0.3 W/kg for 1 mW/cm^2.

Outside the exclusion fence, the average incident power densities will be 0.1 mW/cm^2 or less. The mean SARs and temperature rises would therefore be one-tenth of those cited above. As frequency decreases from 30 MHz to 3 MHz, a further, considerable reduction in SARs occurs. Thus, the likelihood of whole-body temperature rise as a result of heating due to exposure to the fields outside the exclusion fence is negligible.

Similar data for a prolate-spheroidal model of a "medium" rat (0.2 m long and weighing 0.32 kg) indicates that the resonant frequency is approximately 650 MHz (i.e., higher than any of the values for humans), and that the resonant SAR is also larger (about 0.8 W/kg for the rat, compared with about 0.2 W/kg for man per mW/cm^2 of incident power density). Therefore, scaling of data from experimental animals to humans must consider such differences of whole-body SAR as well as frequency. To illustrate this point, the SAR of the medium rat is about 0.2 W/kg per mW/cm^2 (in the E orientation) at 2.45 GHz--a frequency that has been used in many laboratory studies of bioeffects of RFR. Coincidentally, this SAR value is about the same as that for the average man at resonance (70 MHz), but it is 10 times as great as his value at 30 MHz. Therefore, extrapolation of any bioeffects seen in rats from exposure to 1 mW/cm^2 at 2.45 GHz to humans exposed to the same power density at 30 MHz (or lower) would be highly questionable. (The human would have to be exposed to 10 mW/cm^2 to have the same SAR as the rat.) Alternatively, to obtain the same SAR in the medium rat as that for the average man exposed to any given value of power density at 30 MHz (e.g., 1 mW/cm^2) it would be necessary to expose the rat to one-tenth of that power density (i.e., 0.1 mW/cm^2 in this numerical example) at 2.45 GHz.

If model humans were to be standing in bare feet on a wet surface or touching other electrically conductive surfaces (reflectors), their resonant frequencies would be approximately halved, yielding values close to the upper end of the OTH-B frequency range. Also, their mean SARs (at the lower resonant frequency) would be higher. However, because the values of incident power density from the OTH-B transmitter at ground level beyond the exclusion area are much lower than 0.1 mW/cm^2, no changes in body temperature would be expected.

The foregoing discussion of mean SAR is also largely applicable to FM-CW RFR, pulsed RFR, and other types of AM RFR at corresponding carrier frequencies and time-averaged incident power densities. (However, as discussed in the next section, there are several differences in interaction between CW and pulsed RFR.)

An early, significant finding for spherical models of the isolated head assumed to be exposed to plane-wave RFR was the discovery of local regions of relative maximum SAR values. The locations of such regions depend on the size of the head, the electromagnetic characteristics of its layers, and the wavelength of the incident field. These regions have been conveniently dubbed "hot spots," even for combinations of incident power density and exposure duration that would produce biologically insignificant temperature increases at such spots. Pertinent hot-spot data are given in the review cited in Section 4.14.1.1.2.

Results of theoretical analyses of SARs have been verified experimentally. Physical models of simple geometry or in human- or animal-figurine shape have been constructed from synthetic biological materials that have approximately the same electromagnetic characteristics as their corresponding biological constituents; the models were then exposed to sufficient power densities to obtain readily measurable temperature increases, which were measured immediately after irradiation.

Among the qualitative results of general interest obtained with human figurines are that, at frequencies near resonance, the local fields can be much higher for certain regions such as the neck and groin than for other body locations, and that field distributions for nonprimates are quite different from those for primates, a point that needs to be given proper consideration when extrapolating experimental bioeffects findings on laboratory animal species to humans or in comparing experimental results on one laboratory species with those on another species.

4.14.2.2 Quantum Interactions and Nonthermal Effects

For short-range quantum interactions (as defined above) of CW RFR, the discrete frequencies are in the infrared range from about 19,000 to 2,400,000 GHz, and the lower end of this range is about 630,000 times higher than a quantum of RFR at 30 MHz. Conversely, the quantum energy

of 30-MHz radiation is too low (by a factor of more than a million) for such interactions. Therefore, the existence of nonthermal biological effects of CW RFR ascribable to such short-range molecular interaction mechanisms is extremely doubtful.

It has been logically postulated that cooperative or long-range quantum processes in biological entities (or the functions resulting therefrom) could be altered by exposure of the entity to external fields of magnitudes that do not produce heat as the primary or initial product. Much research has been conducted with models of cellular membranes. In general, the results indicate that cooperative processes have activation energies or exhibit resonant frequencies that can be much lower than those for short-range interactions.

The mean thermal energy corresponding to the physiological temperature 98.6°F (37°C) is about 0.027 eV, with a classical spectral distribution around a maximum at 6,500 GHz and encompassing the frequency range for cooperative processes. Therefore, as a counter-argument to the manifestation of such nonthermal effects, a question has been raised of whether these effects would be distinguishable from those that are spontaneously induced thermally <u>in vivo</u>. Alternatively, separation of such RFR interactions from those thermally induced may require that the rates of occurrence of the former exceed the rates for the latter. This requirement implies that for manifestation of such effects of RFR, the intensity of the incident field must exceed minimum values or thresholds related to the specific processes.

Because predictions from various theoretical models and related considerations conflict to a significant extent, the issue of whether weak external fields at frequencies well below the infrared range (i.e., RFR) can alter biological processes is not yet resolved. However, increases and decreases of calcium-ion binding to cell membranes due to weak external RFR, a phenomenon called "calcium efflux," have been ascribed to alterations of cooperative processes by such fields. This phenomenon is discussed in Section 4.14.3.5.2.

4.14.2.3 <u>Interactions of RFR Pulses</u>

Although the RFR from the OTH-B radar is not pulsed, the interactions of high pulse-power-density RFR at low average power densities are discussed here because such interactions are often cited as being "nonthermal" effects. The interactions of individual RFR pulses with an entity (biological or nonbiological) are analogous to those of mechanical impulses; an "impulse" is defined as the sudden application of a force to an entity for a brief time, resulting in an abrupt increase in momentum. The total energy imparted to the entity depends on the magnitude of the force and the duration of its application. The interaction can be characterized as nonthermal or thermal, depending on the properties of the entity that determine the disposition of the energy. The impact of a piano hammer on a string, which excites the string into vibration

at its discrete resonant frequencies (the fundamental frequency and integer multiples thereof, or harmonics) is an example of an essentially nonthermal interaction as defined previously; most of the energy is transformed into sound, which is converted into heat elsewhere.

A sudden blow to an entity such as a block of material having a set of resonant frequencies that are not necessarily harmonically related to one another will excite many of these frequencies; this illustrates the principle that an impulse contains a broad spectrum of frequencies. The results of an impact on a church bell can be characterized as nonthermal for the same reason as that given for the piano string. By contrast, the effects of a blow to a block of lead or asphalt are essentially thermal; even though some sound is produced, most of the energy is converted into heat on the surface of impact.

The temperature increase of any given region within a biological entity due to the arrival of a single RFR pulse and the imparting of its energy to the entity would be small because of the relatively large thermal time constants of biological materials. However, if the region contains a boundary between layers of widely different dielectric properties, the temperature gradient (rate of change of temperature with distance) can be large at such a boundary even though the mean temperature increase in the region is small.

One single-pulse effect known to occur in humans is the phenomenon of "microwave hearing" discussed in Section 4.14.3.5.1 or the perception of single or repetitive short pulses of RFR as apparently audible clicks. The interaction mechanisms involved are not yet completely understood. However, most of the experimental results tend to support the theory that pulse perception occurs because of transduction of the electromagnetic energy into sound pressure waves in the head at a boundary between layers having widely different dielectric properties (e.g., at the boundary between the skull and the skin or the cerebrospinal fluid). The energy in a pulse arriving at such a boundary is converted into an abrupt increase in momentum that is locally thermalized, producing a negligible volumetric temperature increase but a large temperature gradient across the boundary. Under such conditions, rapid local differential expansion would occur and create a pressure (sound) wave that is detected by the auditory apparatus. This effect is often characterized as nonthermal because the power density averaged over two or more pulses can be minuscule. Specifically, the time-averaged power density for two successive pulses is inversely proportional to the time interval between the arrival of the pulses at the perceiver, and this interval can be indefinitely long without affecting the perception of each pulse. Therefore, the time-averaged power density has no relevance to perception. Irrespective of how the RFR-hearing phenomenon is characterized, the significant point is that the preponderance of experimental evidence indicates that the pulses are converted into actual sound waves in the tissues of the head, rather than perceived by direct RFR stimulation of the auditory nerves or the brain.

Pulsed RFR has been reported to produce other effects, such as alterations of the blood-brain barrier and behavioral changes. However, neither the auditory effect discussed above nor these other reported effects are likely to be of concern with regard to the OTH-B radar because its RFR is not pulsed.

4.14.2.4 Effects of Amplitude Modulation Per Se

Insofar as average power density is concerned, the effects of AM RFR at any given carrier frequency and power density are essentially the same as those of CW or FM-CW RFR at the same carrier frequency and power density. In addition, biological effects have been ascribed to amplitude modulation per se, notably the previously mentioned calcium-efflux phenomenon, which was reported for 50-MHz, 147-MHz, and 450-MHz RFR modulated at sub-ELF-band frequencies, and also at some sub-ELF frequencies, but not for unmodulated RFR at these carrier frequencies. However, the calcium-efflux phenomenon is not of concern for OTH-B because the RFR therefrom is FM-CW. Moreover, there is no evidence that frequency modulation causes any biological effects ascribable specifically to the modulation.

4.14.3 Present State of Knowledge Regarding Biological Effects of RFR

All evidence of the biological effects of RFR comes from observations of the results of exposure of humans, animals, or other biological specimens, such as insects, isolated organs, cell cultures, or bacteria. Theory, hypotheses, and speculation may guide experiments and help to explain observations, but in the end they are not, per se, evidence of effects. In this section, therefore, only those papers from the scientific literature that are concerned with actual exposure of biological entities are considered. The reader interested in full details of the papers is referred to the appropriate sections of the review (and critique) cited in Section 4.14.1.1.2.

4.14.3.1 Epidemiology

Epidemiology, as used in this context, refers to studies of whether one or more health-related conditions can be associated statistically with purported or actual exposure of humans to RFR (in contrast with assessments based on extrapolation from data on animals to humans). Epidemiologic results tend to be based on imprecise estimates of exposure characteristics (frequency, power density, and duration). The extent to which the control group matches the exposed group is frequently open to question. Because matching of all relevant factors except exposure is the basis for concluding that any observed differences between groups are related to the RFR exposure, selection of an appropriate control group is critical. Despite these limitations, such studies provide almost the only information available on possible effects of actual RFR exposure in humans.

reexamination, found to have been attributable most likely to uncontrolled factors rather than to RFR exposure. The study with rats failed to find evidence of mutagenic effects.

Studies on the effects of RFR exposure on the structure of chromosomes in cells of plants, animals, and humans did not reveal aberrations at power densities below 20 mW/cm^2.

When scrutinized critically, all of the studies on mutagenic and cytogenetic effects of RFR exposure reviewed indicate that the effects found probably are related to heating. Power density levels outside the exclusion fence of the OTH-B transmitter are incapable of producing significant heating. There is no evidence that such low power densities are likely to cause mutagenic effects. In addition, a report claiming that RFR exposure has increased the incidence of cancer does not withstand critical review. It does not provide evidence that exposure to RFR is likely to cause cancer. Other studies have failed to find an effect of RFR exposure on general health of the exposed animals or on the occurrence of cancer.

4.14.3.3 Teratogenesis and Developmental Abnormalities

Teratogenesis in humans is the production of malformed infants by processes affecting their development in the womb. The term "developmental abnormalities," as used here, refers to processes affecting the development of infants after birth. Teratogenic and developmental abnormalities occur naturally at a low rate in most animal species, and relatively little is known about their cause. In a few cases, however, specific agents have been shown to cause significant teratogenic effects, and hence the possibility of these effects from RFR is an appropriate matter of public concern.

Teratogenic studies with RFR have used a variety of animal models. One set of studies was performed on pupae of a beetle commonly used in scientific experiments. Several reports from different laboratories stated that relatively low levels of RFR would produce developmental abnormalities in the pupae. It later was learned that such abnormalities depended strongly on such factors as the source of the larvae and their diet before they entered the pupal stage. The amount of RFR absorbed was also, as a consequence of the RFR exposure system used, quite high.

Tests for effects on Japanese-quail eggs failed to show significant teratologic or developmental abnormalities resulting from RFR exposure.

RFR has been reported to cause various teratogenic effects in a number of studies using mice. Analysis of the dose-response data indicates an apparent threshold for such effects. At doses less than about 3 cal/g or at power densities less than about 1 mW/cm^2 there is

A group of reports was selected for review from the literature in the United States, Poland, Czechoslovakia, Sweden, and the USSR. These reports provide a representative sample of the kinds of information currently available and comprise studies on many thousands of humans who had been exposed to RFR over periods ranging up to several decades. Endpoints examined included mortality (was lifespan shortened?); cancer induction; birth defects, including mongolism; heart disease; general health tests such as electrocardiograms, standard blood tests, urinalyses, liver function tests, and ophthalmologic, neurologic, gynecologic, psychiatric, and psychological examinations; and (in the Soviet Union) examination for functional changes in the central nervous system described as "vegetative dysfunction accompanied by neurasthenic symptoms." (Such symptomatology is generally not in the lexicon of medicine practiced in the West.) Several epidemiologic studies were also conducted specifically to seek eye defects in persons believed to have been exposed to RFR at military and nonmilitary establishments.

In general summary, none of the U.S., Polish, and Czechoslovakian epidemiologic studies offers clear evidence of detrimental effects associated with exposure of the general population to RFR. However, the Soviet findings, which are consistent with the voluminous Soviet literature from the 1960s, suggest that occupational exposure to RFR at average power densities less than 1 mW/cm^2 does result in various symptoms, particularly those associated with disorders of the central nervous system (CNS). Because the USSR symptomatology has not been reported in Western studies and because of the marked differences between Soviet and Western publications in the procedures used for reporting data, prediction of possible RFR hazards based on the USSR epidemiologic studies would require acceptance of these Soviet findings at face value. Taking all of the epidemiologic studies together, we conclude that the results do not provide evidence that the RFR from the OTH-B radar will be hazardous to the population outside the exclusion fence.

4.14.3.2 Mutagenesis and Cancer Induction

One frequently expressed concern about RFR is that it may cause mutations. Mutagenesis and cancer induction are considered to be related, and indeed many chemicals are screened for potential cancer-causing properties by using bacterial mutation tests. Several studies for mutagenic effects of RFR have been carried out on bacteria, yeast, and fruit flies (standard test systems for mutagenesis). These studies failed to demonstrate a mutagenic effect. No mutations were found that were attributable to RFR exposure.

Other papers described a standard test for mutagenesis called the dominant lethal assay (mutations that result in the death of the embryo) using mice and rats. Marginally positive results for mice were, on

no evidence that RFR is teratogenic. In rats, no significant differences between RFR-exposed and control groups were found in any of the parameters commonly looked for in such studies, even at power densities capable of heating the pregnant females to temperatures over 104°F.

In a study designed primarily to seek possible effects of chronic RFR exposure of pregnant squirrel monkeys on mother-infant behavior, no differences were found between RFR-exposed and sham-exposed mothers in the number of live births or the growth rates of the offspring. There was an unexpected finding of infant deaths in the small group (5 animals) with the highest RFR power exposure. When the study was repeated with a sufficient number of animals for adequate statistical treatment, the RFR-induced offspring mortality finding was not confirmed.

In summary, the studies showing demonstrable teratogenic effects following exposure to RFR have involved power density levels that are capable of producing a significant heat load in the animals. In general, the results indicate that a threshold of heat induction or temperature increase must be exceeded before teratogenic effects are produced. Because the normal human metabolic rate is of the order of 1 to 2 W/kg, the average power densities outside the exclusion fence of the ARS transmit site would not have any significant effect on body temperature that would cause teratogenic effects in humans.

4.14.3.4 Ocular Effects

The fear that RFR can cause cataracts is a recurring theme in newspapers and other popular media. Indeed, given the many investigations with animals by various researchers, it is undoubtedly true that if a person's eyes were exposed to intensities high enough to elevate the temperature of the lens of the eye by about 5°C (9°F) or more, the lens would quickly suffer damage. The lens is the region of the eye most vulnerable to RFR because other regions have more effective means of heat removal, such as greater blood circulation, evidenced by much smaller temperature elevations in these regions than in the lens at the same incident power density. Therefore, the basic concern regarding ocular effects is centered on whether exposure to much lower intensities (i.e., to power-density levels that would produce much smaller lens temperature elevations) for long periods, either continuously or intermittently, can cause eye damage. Implicit to these concerns is whether the effects (if any) of long-term, low-level exposure in the eye are cumulative.

4.14.3.4.1 Humans

Some cases of ocular damage in humans ascribed to occupational exposure to RFR were reported during the 25 years after World War II. Although the exposure histories of these individuals could not be ascertained with any degree of certitude, it is likely that their actual or incipient vision impairment resulted from exposure to average power densities substantially greater than the threshold found in animal studies (about 150 mW/cm^2).

Epidemiologic studies have been conducted to determine whether prolonged exposure to RFR is cataractogenic. These studies are mentioned in Section 4.14.3.1. No reliable reports of eye defects associated with RFR exposure were found.

4.14.3.4.2 <u>Animals</u>

During the past 30 years, various investigations have been conducted on the effects of RFR exposure on the eyes of live experimental animals. Many of the results indicate that intraocular temperature increases of about 5°C or more are necessary for eye damage. Also, no lens opacifications were caused by RFR exposure when the eye was cooled during exposure, indicating that intraocular temperature rise was a major factor in eye damage.

Many of the results of RFR exposure indicate the existence of a threshold average power density of about 150 mW/cm^2 to produce cataracts in experimental animals. The existence of a cataractogenic threshold implies that single or multiple exposure for indefinitely long durations at average power densities well below the threshold would not cause eye damage to humans or any other species.

In summary, on the basis of experimental results with animals that indicate the existence of a threshold power density of 150 mW/cm^2 and the finding of no statistically significant differences between exposed and control groups of humans from epidemiologic studies, there is no evidence that prolonged exposure of humans to the RFR from the OTH-B transmitter at the power densities existing outside the exclusion area is likely to cause eye damage.

4.14.3.5 <u>Studies of the Nervous System</u>

Several types of studies have been conducted on effects of RFR on the nervous system of animals. These studies are considered particularly important in the USSR, where RFR is believed to stimulate the nervous system directly and thereby cause a variety of physiological effects. Scientists in the United States tend to doubt that RFR interacts directly with the nervous system except, possibly, under special circumstances (discussed in the next section), and they consider most effects of RFR on the nervous system to be indirect results of other physiological interactions.

4.14.3.5.1 <u>RFR Hearing Effect</u>

Humans in the vicinity of some types of pulsed radar systems have perceived individual pulses of RFR as audible clicks (without the use of any electronic receptors). This phenomenon has attracted much interest--especially in the United States--because it has often been cited as evidence that nonthermal effects can occur and because an initial hypothesis was that one of the possible mechanisms for perception is

direct stimulation of the CNS by RFR. Various theoretical and experimental studies, the latter both with human volunteers and with laboratory animals, have been conducted to determine the conditions under which pulsed RFR is audible and to investigate the interaction mechanisms involved. Many of the results support the hypothesis that a pulse of RFR having the requisite pulse power density and duration can produce a transient thermal gradient large enough to generate an elastic shock wave at some boundary between regions of dissimilar dielectric properties in the head, and that this shock wave is transmitted to the middle ear, where it is perceived as a click. Persons with impaired hearing are unable to hear such clicks, and experimental animals in which the cochlea (the inner ear) has been destroyed do not exhibit brainstem-evoked responses. However, even though the existence of the RFR-hearing effect is well established, it is of no concern with regard to the OTH-B radar because its RFR is not pulsed, but rather is FM-CW.

4.14.3.5.2 Calcium Efflux

Exposure of samples of brain tissue from newly hatched (neonatal) chicks to RFR amplitude-modulated at low frequency has been reported to increase the rate of exchange of calcium ions between the tissue and the fluid bathing it. This effect has been demonstrated by two groups of investigators. Most of the studies were carried out on isolated tissues maintained in physiological solutions. Similar alterations in calcium ion exchange were reported for exposed brains of paralyzed live cats irradiated at 3 mW/cm^2 with 450-MHz RFR sinusoidally amplitude-modulated at 16 Hz.

Interpreting these results with regard to human health and safety is difficult. First, the phenomenon is subtle. Large numbers of samples have to be processed to show a statistically significant effect. Second, the observations are highly variable and difficult to reproduce. Third, the circumstances of the experimental methodology are such that the observations of changes of calcium exchange appear to apply to the surface region of the brain rather than to the brain as a whole. Finally, the phenomenon depends on the amplitude modulation of the RFR in a narrow frequency band around 16 Hz and only occurs for narrow ranges of average power densities (windows) between 0.1 and 3.6 mW/cm^2. The effect is scientifically interesting, in that it represents a rare instance where RFR may be producing a biological effect by processes other than thermal mechanisms. However, the phenomenon is not directly relevant to OTH-B because the RFR from its transmitter is not amplitude-modulated.

4.14.3.5.3 Blood-Brain Barrier Effects

In most organs and tissues of the body, molecules in the blood can freely diffuse into the tissue around the capillaries. However, presumably to protect the brain from invasion by various blood-borne microorganisms and toxic substances, large molecules such as proteins or polypeptides exhibit little or no movement from the blood into the surrounding brain tissue in most regions of the brain. The exact manner

by which the movement is prevented is still conjectural, but the process is referred to as the "blood-brain barrier" (BBB). The BBB can be "opened" by certain agents (e.g., ionizing radiation, heat) or chemical substances (e.g., dimethyl sulfoxide). Studies have been conducted to examine whether RFR can alter the BBB permeability of animals to various large molecules.

Early studies suggested that RFR at relatively low levels could affect BBB permeability in the rat. Later studies were unable to confirm these findings, and indeed found that the results were likely to have been artifacts introduced by the experimental techniques that had been employed. At higher power densities sufficient to cause heating (above several mW/cm^2), RFR does appear to cause alteration in BBB permeability to various substances.

On the basis of current evidence, it is quite unlikely that exposure of people to the levels of RFR existing at ground level outside the exclusion fence of the ARS transmit site would have any effect on the permeability of the BBB because the levels of RFR are insufficient to cause heating of the brain.

4.14.3.5.4 Histopathology and Histochemistry of the Central Nervous System

Histopathology is defined as the study of diseased or damaged tissues, and histochemistry as the study of the chemical composition of various tissues. Studies of histopathological effects of RFR on the brain have been conducted in both the United States and the USSR. Studies in the USSR have covered a wide range of frequencies, but the reporting of dosimetry and methods was in many instances inadequate to enable a critical evaluation of the validity of the experiments or of the findings. In the United States, studies of histopathological effects of RFR on the brain have been performed on hamsters and rats, where effects have been seen, and on squirrel monkeys, where effects have not been seen. The levels of RFR to cause the effects in rodents were 10 mW/cm^2 and higher, which, because of a resonance phenomenon between the skull of such a small animal and the RFR frequency used, could have resulted in high RFR absorption levels in the brain. The observed effects seem likely, therefore, to have resulted from thermal processes.

Other studies have examined effects of RFR on brain neurochemistry. One showed no effects on specific neurotransmitters of mouse brain; the other showed small (5% to 10%) changes in tissue respiration of subcellular components. The significance of this latter finding is unclear, but it is not likely to be indicative of a hazard because of the wide range of tissue respiration values possible in various environments and activities.

In summary, RFR can cause observable histopathological changes in the CNS of animals but it appears that these changes are thermal. Under

special conditions of frequency and skull size, a focusing effect can be obtained in small rodents, causing local SARs tens of times higher than would normally be expected from whole-body SAR measurements. Such conditions do not occur for the adult human skull. One study has reported small changes in brain tissue respiratory chain function at a power density of 5 mW/cm^2. It is unlikely that such effects would be detectable at the power densities at ground level outside the the ARS transmitter exclusion fence. These studies provide no evidence that exposure to such power densities are likely to be hazardous.

4.14.3.5.5 Electroencephalogram (EEG) Studies

Studies have been conducted to ascertain the effects of RFR on the EEG or other related electrophysiological properties of the CNS. For EEG measurements made after RFR exposure, the time consumed in placing and attaching the electrodes and the variability of placement introduce problems of interpretation. Additionally, if the effects are transient, they may stop when exposure ceases. For studies attempting to measure EEG changes during application of the RFR, the electrodes and leads used to pick up EEG signals also pick up electrical signals directly from the fields, causing artifacts that render the recordings difficult to interpret. In addition, indwelling or chronically attached electrodes will perturb the electric fields in their vicinity and produce great enhancement of energy absorption, thereby creating still another artifact in the biological data. To meet these problems, specially designed indwelling electrodes of high-resistivity materials that do not cause field perturbation have been constructed and used in a few of the more recent studies.

Experiments in which such specially constructed electrodes were used, or in which electrodes were applied after exposure, show no evidence of statistically significant differences in EEGs or in evoked responses between control and RFR-exposed animals. There is therefore no evidence that ground-level RFR from the ARS transmitter is likely to cause any effects on the EEG or evoked potentials of populations outside the exclusion fence. One study does indicate the possibility that persons with indwelling metallic electrodes in the brain or prosthetic metallic plates on the skull may have effects induced in their EEGs or evoked potentials in the vicinity of the exclusion fence, where the highest average power density is about 0.1 mW/cm^2, but only if they are there for extended periods (several months).

4.14.3.6 Effects on Behavior

Many experimental studies have been conducted on the effects of RFR on animal behavior. The results of such studies are considered particularly important in the USSR, where they are often considered to be evidence for direct effects of RFR on the CNS. Scientists in the United States do not always agree that behavioral effects necessarily imply direct effects on the CNS. However, behavioral effects are very sensitive indicators of biological function and hence receive

appropriate attention in both Eastern European and Western countries. The papers described in the review were selected as representative of the types of behavioral studies that have been conducted. These include studies of effects on reflex activity, studies of RFR-perception, evaluations of effects of RFR on learning and on performance of trained tasks, studies of interactive effects of RFR and drugs on behavior, and investigations of behavioral thermoregulation. Studies have been conducted on mice, rats, rabbits, squirrel monkeys, rhesus monkeys, and humans.

Again, conflicts occur between Soviet claims of effects at low (equal to or less than 0.5 mW/cm^2) power densities for long-term exposures and the absence of similar effects in the same power density range in the studies by U.S. researchers. The validity of the Soviet claims is difficult to assess because of lack of reported detail of the experiments. It is certainly likely that such effects could be seen if indwelling electrodes were used for the animals involved in the Soviet studies, but whether such was the case is unknown.

In summary, and with the above qualification, RFR is capable of producing alterations in a wide variety of behaviors of various species of animals. Except for pulsed RFR, the average power densities required to modify behavior are almost all at levels of approximately 5 mW/cm^2 and above, and most appear to be in the thermal range. Perception of pulsed RFR is a peak-power phenomenon, not an average-power one (as discussed in Section 4.14.3.5.1). Pulsed RFR can thereby modify behavior. However, it is not relevant to the OTH-B radar, which is an FM-CW rather than a pulsed system.

It is difficult to relate most of the behavioral studies in animals to humans. All behavioral studies are directly relevant to the nature of the species being studied, and the conclusions of a given study do not readily transfer to other species. Because of the power densities needed to cause reported effects, however, these studies provide no evidence that exposure to RFR at the levels outside the ARS exclusion fence is likely to have adverse effects on human behavior.

4.14.3.7 Endocrinological Effects

Exposure of animals to RFR has produced somewhat inconsistent effects on the hormone-secreting (endocrine) system of mammals. In general, the effects produced appear to be related either to stress induced in the animals by the heat load associated with the RFR or to perception of the RFR and, possibly, other experimental circumstances. Some effects also appear to be secondary to alteration of the circadian rhythm by heat stress resulting from RFR exposure, but these effects are subtle and of dubious relevance to the low levels of the OTH-B system. There do not appear to be any effects clearly demonstrated to be associated with nonthermogenic stimulation of the endocrine system or the associated parts of the CNS.

Although some of the effects of RFR exposure on the endocrine system (e.g., results from heating of the testes by RFR) appear to be relatively straightforward and predictable from physiological considerations, other, more subtle effects require further study--notably those related to the interactions among the pituitary, adrenal, thyroid, and hypothalamus glands and/or their secretions. There is currently no evidence that such subtle effects are hazardous. Part of the problem in interpreting results appears to arise from uncertainties regarding stress mechanisms and accommodations thereto. Animals that are placed in novel situations for an experiment are much more prone to exhibit stress responses than animals that have been adapted to the situation. However, the variations in adaptation among animals may be large in a given situation or among experimental situations in different laboratories.

In conclusion, because the reported effects of RFR on the endocrine systems of animals are largely ascribable to increased thermal burdens, to stresses engendered by the experimental situation, or to both, there is no evidence that such effects would occur in humans exposed to the RFR from the ARS radar outside the exclusion fence.

4.14.3.8 Immunological Effects

Studies to date indicate that RFR has quite definite effects on the immune system of mammals. Most of the reported effects were detected after exposure at power density levels of about 10 mW/cm^2 and higher; a few have been detected following exposure to power densities as low as about 0.5 mW/cm^2; and in some cases, effects obtainable with the higher power-density range were not found at lower power densities, indicating the possibility of a threshold power density for the effect. In most studies, the mechanisms for the effects seen were not investigated, and the various reports are somewhat inconsistent. The situation is complicated by the complexity of the immune system and the variety of test procedures used.

Some studies suggest suppression of immune system function, some suggest stimulation, and others, both effects. Furthermore, results from various laboratories obtained under apparently comparable conditions are sometimes contradictory and indicate the probable presence of uncontrolled factors or subtle differences in the experimental protocols.

Given current findings, it appears that RFR-induced effects on the immune system of intact animals depend to varying degrees on the ages of the experimental subjects, the frequency and average power density of the RFR (or the whole-body SAR resulting therefrom), the exposure duration and perhaps the time of day when the exposures are given, the kind of exposure system used (which affects the internal SAR distributions within the animals), and the kind of endpoint analyses undertaken and when they are performed relative to the completion of exposures.

Reported effects on the immune systems of intact animals from chronic exposure to RFR at average power densities below 1 mW/cm^2 are unlikely to be linked simply to temperature increases, but such results have not yet been repeated elsewhere. In most other similar investigations, the exposures were at average power densities exceeding 1 mW/cm^2. The existing evidence indicates that some of the immune-system effects are probably mediated through the effect of RFR on the endocrine system, involving the general syndrome of adaptation to stress. The mechanisms and significance of such effects are not yet understood, nor have individual findings been independently verified. There is no evidence that the RFR effects on the immune systems of animals reported would occur in humans chronically exposed to the levels of RFR from the OTH-B radar outside the exclusion fence or that such effects would be hazardous to human health.

4.14.3.9 Biochemical and Physiological Effects

The literature on biochemical and physiological effects associated with RFR is extensive. Many of the reported effects are associated with other events (e.g., changes in hormonal levels or stress adaptation); some are questionable for various reasons, and others do not have a clear medical significance.

The thermal basis for most of the reported physiological and biochemical effects of exposure of intact animals to RFR is evident. Most significant with respect to possible hazards of human exposure to RFR are the investigations with nonhuman primates because their anatomies and physiological characteristics are closer to those of humans than are those of other experimental animals. The results with rhesus monkeys showed that exposure to RFR at frequencies in the HF range at average power densities of the order of 100 mW/cm^2 were well with.- the thermoregulatory capabilities of this species. Also noteworthy were the negative findings of the blood-chemistry assays performed on rhesus monkeys 1 to 2 years after exposures to such high power densities and observations that the thermoregulatory system of the squirrel monkey is quite effective in compensating for RFR exposure.

The investigations involving exposure of intact, smaller species of mammals to RFR have yielded a variety of positive and negative results. Some of the positive findings are also clearly due to the additional thermal burden imposed by the RFR. Other results, such as those on decreased food intake and lower blood glucose levels in rats, indicate the existence of an SAR threshold of about 1 W/kg or higher for such effects.

One physiological aspect of concern is whether exposure of humans to RFR can affect their heart functions. In early work on this subject with excised turtle, frog, or rat hearts, various investigators reported RFR-induced bradycardia (decrease in pulse rate), tachycardia (increase in pulse rate), or both (depending on average power densities, with bradycardia for the lower range of power densities used). The lowest

SAR at which bradycardia was observed in the isolated turtle heart was 1.5 W/kg. More recently, no RFR-induced changes were found in beat rate or contractile force in isolated atria of rat hearts exposed to 2.45-GHz CW RFR at 2 or 10 W/kg.

SAR-dependent changes in heart beat rate in intact animals were also reported. The results indicate the existence of a threshold between 4.5 and 6.[illegible] W/kg, many orders of magnitude higher than could occur outside the exclusion fence of the ARS transmitter.

Overall, the general conclusion of the review is that the occurrence of physiological or biochemical effects from exposure to the RFR from the ARS transmitter at the levels expected outside the exclusion fence is extremely improbable.

4.14.3.10 Effects on Small Animals within the Exclusion Fence

As described in Section 4.14.2.1, thermal energy absorbed from an electromagnetic field is usually characterized by the specific absorption rate (SAR). This is defined as the rate of energy absorption per unit volume in a small volume at any locale within an entity, divided by the mean density of the constituents in that volume. The usual units of SAR are W/kg. Whole-body SAR, representing the spatial average for the body, is the measure most used in practice because it can be measured experimentally without requiring information on the internal SAR distribution.

Given the size and orientation of an animal with respect to an incident RF field, it is possible to calculate the whole-body SAR. From Table B-2, the highest near-field power density occurs for band F: 258 mW/cm^2. The field for this band is vertically polarized. A human in the field is therefore parallel to the E-field, a condition resulting in the greatest absorption of RFR. Quadruped animals are perpendicular to the E-field and absorb somewhat less RFR. Absorption also depends on the size of the animal relative to the wavelength of the incident field.

Calculated whole-body SARs are given in Table 4-8 for man and for representative small animals that might live within the exclusion fence. The 1982 ANSI C95.1 Radiation Protection Guide for humans is based on permissible unrestricted exposure of the body resulting in an SAR of 0.4 W/kg, spatially and temporally averaged over the entire body. From the table, the human SAR exceeds the ANSI Guide by a factor of 13. However, the smaller animals have much lower SARs.

The literature on RFR biological effects indicates that whole-body SARs associated with thresholds of potentially harmful effects occur in the range between 4 and 8 W/kg. Therefore, no effects on small animals living inside the exclusion fence from the relatively high levels of RFR would be discernible, even though such levels would be potentially harmful to humans.

Table 4-8

MAXIMUM WHOLE-BODY SARS INSIDE THE EXCLUSION FENCE[a]

Entity	Whole-Body SAR (W/kg)
Human (154 lb)	5.2
Beagle-sized dog (30 lb)	0.26
Rabbit (2.2 lb)	0.052
Large mouse (1 oz)	0.026

[a]Incident field 28 MHz, vertical polarization, 258 mW/cm^2.

Source: Durney et al. (1978).

4.14.4 Misconceptions

Several misconceptions regarding RFR bioeffects continue to be expressed in popular accounts outside peer-reviewed scientific publications on the subject. Those accounts tend to be sources of some confusion for the nonspecialist. Representative examples follow.

The distinction between RFR and ionizing radiation is often not made; consequently, the known hazards of ionizing radiation are linked--by implication--with exposure to RFR. In essence, ionizing radiation (which includes ultraviolet light, X-rays, and the emissions from radioactive materials) has sufficient quantum energy (see Section 4.14.2.1) to expel an electron from a molecule, leaving the molecule positively charged and thereby strongly affecting its interactions with neighboring molecules. Ionization can alter the functions of biological molecules fundamentally and often irreversibly.

By contrast, the quantum energies of RFR are so much smaller that their primary effect is to agitate molecules rather than to ionize them. (The possibility of long-range quantum interactions, discussed in Section 4.14.2.1.3, is not excluded; however, evidence of their occurrence in live animals is sparse as yet, and there is no evidence that such effects would be harmful if they did occur.) Also, RFR-induced agitation ceases as soon as exposure to RFR is halted. At low RFR intensities, the heat that such agitation represents is well accommodated by the normal thermoregulatory capabilities of the biological entity exposed, and therefore such effects are generally reversible. At high RFR intensities, the thermoregulatory capabilities may be inadequate to compensate for such effects, and exposure at such intensities may

lead to thermal distress or even irreversible thermal damage. In short, a single quantum of ionizing radiation that is absorbed by a molecule alters the properties of that molecule, and exposure to such radiation may thereby profoundly affect the function of the biological constituent involved, whereas the concurrent absorption of many quanta of RFR is necessary to cause biologically significant effects.

Even if an effect is produced by RFR, that effect may not necessarily be deleterious to the entity involved. As an example of a nonhazardous biological effect, the absorption of visible light (a form of electromagnetic radiation having quantum energies above those of RFR but below those of the ionizing radiations mentioned previously) in the eyes is necessary for vision. Light is also absorbed by the skin and at normal levels is converted into harmless heat. One of the reasons that the levels of allowable exposure of humans to RFR are generally lower in Eastern European countries than they are in the West is the philosophically based assumption that even small RFR-induced effects are potentially harmful--a view not generally shared in Western countries.

Concerned people often ask whether guarantees can be offered that chronic exposure to low levels of an agent such as RFR will have no deleterious effects many years in the future. It is scientifically impossible to obtain data on which a guarantee of absolute safety can be based. An infinitely large number of experiments to test all hypothetically hazardous situations would have to be performed. However, the large body of experimental data on RFR bioeffects indicates that, unlike the ingestion of certain substances in small quantities that can accumulate into a potentially harmful dose, RFR energy continually absorbed at low incident power densities (dose rates) is readily dissipated and does not accumulate in the body toward the equivalent of RFR energy absorbed at high incident power densities. This is one of the basic reasons for the existence of threshold power densities for the various RFR bioeffects.

4.14.5 Unresolved Issues

The potential biological effects of RFR have been assessed from existing studies at frequencies up to 300 GHz. Based on the studies evaluated, with recognition that the negative findings reported in some studies may have been obtained because the experiments had been poorly conducted, no reliable evidence exists to indicate that chronic exposure to RFR at incident average power densities below 1 mW/cm^2 or at SARs below 0.4 W/kg is likely to be hazardous to human health. However, certain gaps remain in our knowledge of the biological effects of RFR.

(1) Epidemiologic Studies. Epidemiologic studies of effects of exposure of humans to RFR, in which the actual frequencies, levels, and durations of exposure are accurately known and quantified, are lacking. Existing epidemiologic studies, while extensive and reasonably well done, have inherent defects, such as unavailability of complete medical records,

death certificates, or health questionnaires, or imprecise classification of the individuals with regard to RFR exposure.

(2) Extrapolation of Findings on Animals to Humans. Obviously, the most directly applicable experimental evidence relevant to possible bioeffects of exposure to the RFR from any specific system such as the ARS radar would be from studies in which humans were exposed to the frequencies and waveform characteristics of that kind of system for appropriate durations at the pulse and average power densities likely to be encountered. Furthermore, quantitative evaluation of a large number of biological endpoints would be necessary. Such data, of course, do not exist. Instead, data are obtained from laboratory animals (mostly small rodents) used as surrogates for humans, a standard practice for investigating the effects of other agents. Because of the biological differences among species, a basic uncertainty is the degree of validity of this practice, which depends in part on the species used, the nature of the agent and its quantitative aspects, and the biological endpoints studied. In investigations of RFR bioeffects, much progress has been achieved in quantifying exposures in terms of whole-body SARs and internal SAR distributions in animal carcasses and in physical and mathematical models of various species (including humans). For example, such data can be used to determine what the whole-body SARs would be in humans at a frequency in the 5- to 28-MHz range, if, say, laboratory rats are exposed to 2.45-GHz RFR at prespecified power densities. Nevertheless, significant gaps in knowledge remain regarding internal SAR distributions in humans. Moreover, most such interspecies calculations do not endeavor to account for the roles of blood flow and other factors in determining heat flow patterns or of thermoregulatory mechanisms in mammals that maintain constant body temperatures.

(3) Thresholds and Long-Term, Low-Level Studies. Most experimental data indicating the existence of threshold power densities for various RFR bioeffects were obtained from exposures for relatively short durations. Although it is difficult to conceive of mechanisms whereby RFR exposures at well below threshold values over a long time could result in cumulative effects deleterious to health, very few investigations have involved exposure of animals to low-level RFR over a large fraction of their lifetimes.

In light of these gaps, the possibility that new information would reveal a significant hazard from chronic exposure to low levels of RFR cannot be dismissed, but is judged to be relatively low.

4.14.6 Conclusions

Epidemiologic studies performed in the United States and other countries do not provide adequate scientific evidence that environmental levels of RFR constitute a hazard to the general population.

Most U.S. experiments with animals that yielded recognizable and repeatable effects of exposure to RFR were performed at whole-body average SARs of more than about 1 W/kg. Such effects are thermal, in the sense that the RFR energy is absorbed by the organism as widely distributed heat that increases the whole-body temperature, or as internally localized heat that is biologically significant even with functioning natural heat-exchange and thermoregulatory mechanisms operating. The existence of threshold incident average power densities has been experimentally demonstrated for some effects and postulated for others. Exposure to RFR at average power densities exceeding the threshold for a specific effect for durations of a few minutes to a few hours (depending on the value) can cause irreversible tissue alterations. The heat produced by indefinitely long or chronic exposures at power densities well below the threshold is not accumulated because its rate of production is readily compensated for by heat-exchange processes or thermoregulation. Most investigations involving chronic exposures of mammals yielded either no effects or reversible, noncumulative behavioral or physiological effects for average power densities exceeding 1 mW/cm^2 and whole-body SARs of 1 W/kg. In the few cases in which irreversible adverse effects of exposure were found, such effects were absent for average power densities below 1 mW/cm^2 and whole-body SARs below 1 W/kg.

In a relatively small number of investigations, biological effects of RFR were reported at incident average power densities less than about 1 mW/cm^2. Such effects have been called "nonthermal," to distinguish them from those considered above. However, this usage of "nonthermal" is confusing and imprecise because the interaction mechanisms involved in each such effect differ considerably from those for the other effects, and clear distinctions between "thermal" and "nonthermal" based on precise scientific definitions of these terms are difficult to discern in the interactions. Among the so-called nonthermal effects of RFR that have been documented to date are the RFR auditory phenomenon and the calcium-efflux effect. However, because the SAR radar will emit FM-CW RFR rather than pulsed- or amplitude-modulated RFR, neither phenomenon is relevant to OTH-B operation. Moreover, no known effects have been attributed to the frequency modulation per se of FM-CW RFR.

In summary, the review of the relevant literature indicates that no reliable scientific evidence exists to suggest that chronic exposure to the RFR from the ARS outside the exclusion fence would be deleterious to the health of even the most susceptible members of the population, such as the unborn, infirm, or aged.

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Appendix A

RADAR AND ANTENNA CHARACTERISTICS

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Appendix A

RADAR AND ANTENNA CHARACTERISTICS

A.1 Introduction

This appendix describes the principal characteristics of the OTH-B radar system. It is quite similar to an experimental radar system that was installed and subjected to extensive testing at sites near Columbia Falls and Moscow, Maine. The Maine facility is now under construction as an operational radar system, designated the AN/FPS-118, with 180° coverage. A second AN/FPS-118 system in northern California and southern Oregon is in the site preparation phase.

The Alaskan Radar System (ARS) would be similar to the systems under construction in Maine and on the West Coast, with the possibility of design changes to improve system performance. The principal difference is that this system would cover 120° in azimuth and would use a somewhat wider frequency band. The Central Radar System would be similar in design and operation.

A conventional radar operates by transmitting a pulse of electromagnetic energy and then waiting to receive energy reflected back to its antenna from some object (target) illuminated by the pulse. Such a radar interprets the time interval between the transmitted pulse and the return as a measure of the distance from the radar to the target. The OTH-B system achieves the same goal by a somewhat different method (see Section A.3).

It is highly advantageous for a radar to concentrate its transmitted energy (and to limit its receiving capability) in a relatively narrow beam. A narrow beam permits greater certainty regarding the direction in which the energy was sent and from which it returned, thus better defining the direction from the radar to the target. A narrow beam also conserves the available energy because it concentrates it into a single direction; finally, it permits reception of weaker returns from a particular direction by discriminating against electromagnetic noise or extraneous, interfering signals that may arrive from other directions.

The resulting OTH-B beam is stepped in azimuth in increments of 7.5°; thus, 8 steps are required to cover the 60° sector assigned to each antenna array. The beam dwells on a particular azimuth for an interval long enough to obtain a return, but not exceeding 10 seconds. Therefore, a given azimuth will be revisited in an interval not exceeding 80 seconds.

Radars have long used parabolic reflectors, or dishes, to form beams in the same manner that the silvered reflector of an automobile headlight forms a beam from the light emanating from the lamp's filament. To move the beam, the radar dish and the radiating element are typically rotated at a particular fixed rate to sweep past a given azimuth every second or so. The need for mechanical motion limits the speed of scanning in such radars.

The OTH-B radar differs from a conventional, microwave radar in many important details. Instead of a single antenna, it uses separate antenna systems for transmitting and receiving; instead of being together, the transmitting and receiving systems are separated by many miles; instead of radiating power in brief pulses separated by long periods of rest, it radiates continuously; instead of using frequencies within a relatively narrow band, it uses frequencies that may vary through a very wide range; and instead of following a straight line to and from the target, the waves are refracted by the ionosphere and reach targets far beyond the horizon of the radar site.

A.2 The Frequency Band

A.2.1 Equipment Capability

To perform its function, the OTH-B radar can choose any frequency in the 5.0- to 28.0-MHz band, corresponding to wavelengths in the 60- to 10.7-m range.* These wavelengths are as much as 600 times longer than those used by a typical "S-band" microwave radar with a wavelength of 10 cm and a frequency of 3,000 MHz. Unlike S-band waves, these relatively long waves are bent by the ionosphere and return to the earth well beyond the horizon, where they can reach and detect targets (see Section A.5). The properties of these waves create many difficult design problems, however. The frequency used at any particular time is chosen to optimize results; the best frequency depends on the object to be detected and the atmospheric conditions that prevail.

A.2.2 Excluded Frequencies

Although the transmit antenna system of the OTH-B radar can generate and radiate any frequency between 5.0 and 28.0 MHz, numerous frequency bands within this overall range are assigned to other users and avoided by the OTH-B system. A representative list of such frequencies is given in Table A-1.

---

*As noted later, the system is programmed to avoid frequencies assigned to other services or on which excessive interference exists.

Table A-1

DISTRESS, CALLING, AND GUARDED FREQUENCIES

Frequency (MHz)	Allocated Services
5.000 ± 0.005	Standard Frequency
5.320 ± 0.005	International Ice Patrol
5.680 ± 0.020	SAR Control--Atlantic and Pacific
5.6814 ± 0.020	SAR Control--Atlantic and Pacific
6.204 ± 0.020	SAR Control--Atlantic and Pacific
6.2054 ± 0.020	SAR Control--Atlantic and Pacific
6.273 ± 0.010	Aircraft Communication to Maritime Mobile Stations
7.5084 ± 0.020	Hurricane Warning Net
7.530 ± 0.020	Emergency Net--Atlantic and Pacific Area
8.364 ± 0.020	SAR Control--Atlantic and Pacific
8.502 ± 0.005	International Ice Patrol
8.7564 ± 0.005	International Ice Patrol
10.000 ± 0.005	Standard Frequency
11.515 ± 0.020	Emergency Net--Atlantic Area
12.150 ± 0.020	Emergency Net--Atlantic Area
12.546 ± 0.010	Aircraft Communication to Maritime Mobile Stations
12.750 ± 0.005	International Ice Patrol
14.993 ± 0.005	Mobile Distress and Calling
15.000 ± 0.010	Standard Frequency
16.728 ± 0.010	Aircraft Communication to Maritime Mobile Stations
18.1975 ± 0.020	Emergency Net--Atlantic Area
18.7225 ± 0.020	Emergency Net--Pacific Area
19.993 ± 0.005	Mobile Distress and Calling Standard Frequency
20.000 ± 0.005	Standard Frequency
20.007 ± 0.020	SAR Control--Astronauts and Space Vehicles
22.245 ± 0.010	Aircraft Communication to Maritime Mobile Stations
25.000 ± 0.005	Standard Frequency

Note: Bandwidths are representative.

A.3 The Modulation

Conventional radar systems use pulse modulation (i.e., they switch the transmitter off and on, generating pulses that are brief compared to the intervening intervals) and determine the range or distance to a particular target by measuring the time that elapses between the departure and the return of a pulse. A disadvantage of this procedure is that the transmitter and all its associated components must be capable of handling peak power levels that are much higher than the average levels. The OTH-B system overcomes this difficulty by continuously transmitting a signal with a frequency that varies with time at a constant rate (linear sawtooth FM). The difference between the frequency being returned from a target and the frequency being transmitted at any instant is a measure of the time delay and hence the target distance. Radars of this kind are often called FM/CW (frequency modulated/continuous wave) systems.

Details of the waveform used are shown in Figure A-1. The center frequency, f_0, is selected in 1-Hz increments to optimize detection in the preferred range of distances. The extent of the frequency deviation or occupied bandwidth B and the waveform repetition frequency that sets the time duration T are independently chosen from the values presented in Table A-2.

Table A-2

MODULATION PARAMETERS OF THE OTH-B RADAR

Occupied Bandwidth, B (kHz)	Waveform Repetition Frequency (Hz)
5	10 to 20 Hz, 2.5-Hz steps
10	
20	20 to 60 Hz, 5-Hz steps
40	

A.4 Separation of Sites

In conventional, pulsed radars, the transmitter is silent (turned off) most of the time; in these intervals, the receiver can "listen" for weak echoes that are returned from distant objects. Because OTH-B modulation provides no such quiet times, and the strong transmitted signals would overload any sensitive nearby receiver, the receiving and transmitting systems must be separated by many miles. In this way, the signals that pass directly from transmitter to receiver are weakened enough to avoid overloading and desensitizing the receiver.

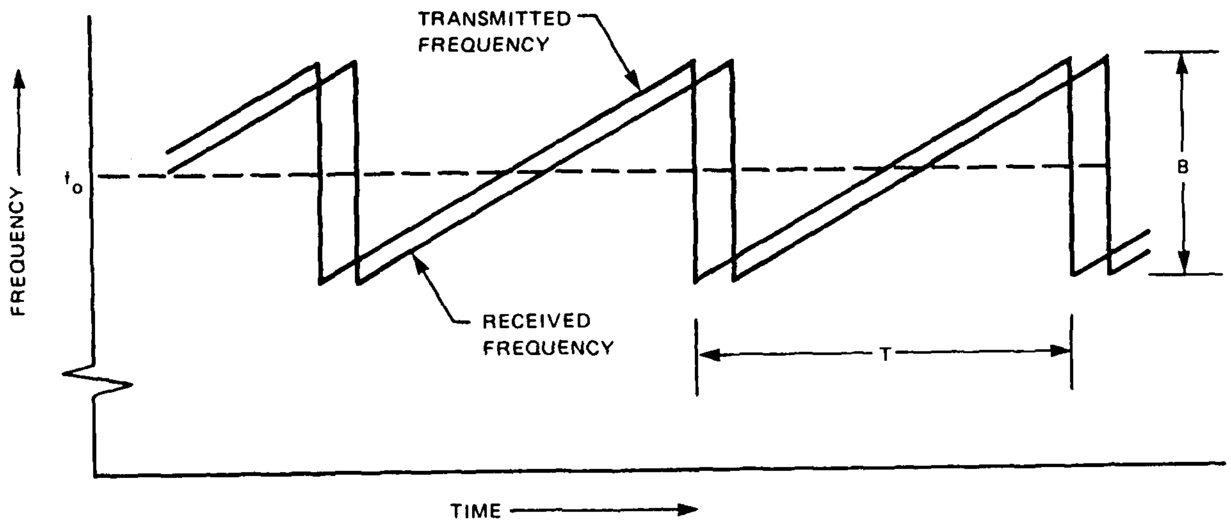

FIGURE A-1 TYPICAL MODULATION WAVEFORM OF OTH-B RADAR

A.5 Propagation

Because microwave signals travel along paths that are almost straight, microwave radar systems are limited to line-of-sight paths. In contrast, radio waves with frequencies in the general range of 5 to 28 MHz are refracted in the ionosphere, which is an ionized layer at an altitude of about 200 miles; they return to the earth's surface at a distance of about 1,000 miles. Any large object such as a ship or airplane that is on or near the surface at ranges between about 500 and 2,000 miles will reflect some incident energy and return a very small fraction of it to the receiving antenna.

The properties of the ionosphere depend on latitude and longitude, the time of day and year, sunspots, and other influences. They are constantly changing and not easily predictable. The frequency and modulation that give the best radar performance depend on existing ionospheric conditions. These considerations force the radar designer to provide great flexibility in the choice of frequency and modulation. The OTH-B radar system has the necessary flexibility.

A.6 The Antennas

To concentrate an adequate power density on distant targets, the OTH-B radar must use a transmit antenna that is both large and efficient. These considerations dictate the choice of multiple-element arrays. Moving such arrays to steer the beam is impractical; therefore, beam steering is accomplished by varying the phase (timing) of the currents delivered to the various elements.

Because long wavelengths and high levels of power are used, the elements of the transmit antenna array are large and expensive; consequently, using many elements is impractical, and the directional accuracy of the transmit antenna array is relatively low. To compensate, the OTH-B system uses receive antenna arrays with numerous elements and a high degree of directivity. In Alaska, the receive antenna system would consist of two arrays or antenna faces, each covering 60° of azimuth and the full frequency band. Although essential to the operation of the system, the receive antenna system is not discussed in this appendix because it does not radiate power.

A.6.1 The Transmit Antenna Array

Because it is impractical to design a single transmit antenna array that achieves the objectives of the OTH-B radar throughout the entire band of assigned frequencies, two antenna arrays consisting of six separate subarrays are used. Only one subarray in each face transmits at any given time. Each subarray consists of 12 elements, uniformly spaced in a plane in front of a vertical conducting backscreen. Each of the six subarrays that make up one antenna face is identified by a letter from A to F; all are aligned over a common groundscreen. Each subarray serves

a scan sector of 60° and a specific band of frequencies. Thus, there are 2 sets of 6 subarrays, for a total of 12 transmitting antenna subarrays. Both the groundscreen and backscreen are constructed of corrosion-resistant wire mesh. The width (in the smaller dimension) of the groundscreen is 750 ft. The height of the backscreen varies from band to band, according to the wavelength.

A.6.2 Formation of the Beam

The currents that are forced to flow in the dipole elements of a driven array induce currents in adjacent portions of the backscreen and groundscreen; these induced currents contribute to the total radiation. The situation is comparable to a lamp bulb near a corner where two mirrors meet at right angles. A single bulb appears as four bulbs, and the brightness is enhanced by a factor of four. The mathematical procedure based on this idea is called the method of images, and radiation is calculated by adding fictional "image" radiators at suitable locations.

If the antenna was located on a flat, perfectly conducting surface, the radiation intensity would be a maximum in the horizontal direction.* Because of the imperfect conductivity of the earth, the lower rays are absorbed or "scraped off," and maximum radiation intensity occurs at an elevation angle of about 10°.

This concept is represented in Figure A-2, which illustrates how the main beam of the OTH-B radar is formed. For clarity, the representation is limited to band E and to the special case in which all elements are driven in the same phase so that the beam axis is perpendicular to the backscreen. The (horizontal) 3-dB beamwidth of a 12-element array of this kind is 8.4°; that is, the intensity of the beam decreases by a factor of two at angles ± 4.2° from the beam axis.

A.6.3 Beam Shaping

The highest possible gain, corresponding to maximum power density on a distant target, is achieved by delivering an equal amount of power to each of the 12 elements in the operating subarray. Although this is usually a desirable operating condition, better results can sometimes be achieved by reducing the amount of power delivered to the elements farthest from the subarray center. Doing so widens the beam and reduces the power density but greatly reduces the power in the sidelobes. The calculations in Appendix B are based on uniform power distribution, which creates maximum values of both instantaneous maximum and time-averaged power density at all locations near the transmitting array.

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*This statement is strictly accurate only for bands E and F that use vertical radiating elements.

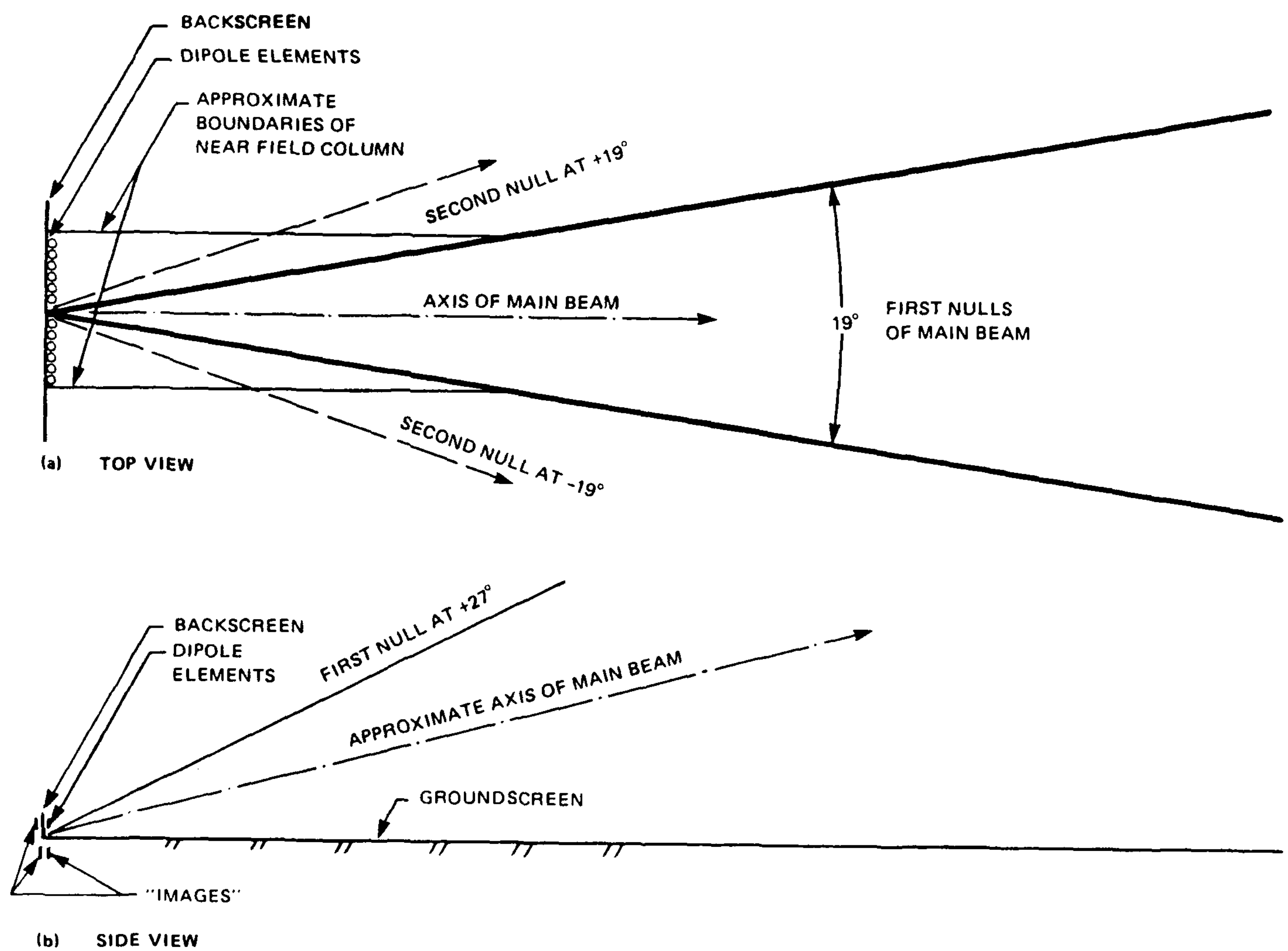

FIGURE A-2 FORMATION OF MAIN BEAM OF OTH-B RADAR (BAND E)

A.6.4 Grating Lobes

If the spacing of the antenna elements in a phased array such as that of OTH-B exceeds half a wavelength, additional lobes (known as grating lobes) can appear in the antenna radiation pattern. They are formed by the radiation from the elements adding in phase and forming additional wavefronts in directions for which the relative path lengths are integral multiples of one wavelength. When circumstances permit, grating lobes first form parallel to the array face (i.e., at 90° from the boresight direction), at the highest operating frequency of the array, and when the main beam is at the maximum scan angle. Unless suppressed in some way (e.g., by the directional pattern of the individual radiating elements), the grating lobes could have an intensity equal to that of the main beam. In the AN/FPS-118 radar, and in any practical phased array system, the element spacing is chosen to prevent grating lobes from forming.

In the arrays of the OTH-B radar, the element spacing is approximately 0.58 wavelengths at the highest frequency in each band, and the maximum scan angle is 30°. Taken together, these limitations preclude the formation of grating lobes.

A.7 The Sounders

Associated with each array of the transmit antenna system is an oblique-incidence sounder that consists of a swept-frequency transmitter and a broadband antenna. The frequency of the sounder is swept continuously from 2 to 30 MHz at a rate of 100 kHz/s. Sounder transmissions are locked out when the sweep generator passes through excluded frequencies. The functions of the sounder are to probe the path to and from the target area and to provide data that will assist in choosing the best frequency for the radar transmitter. The power radiated by the sounder is 10 kW, and the gain of the sounder antenna is less than that of the main antennas. Therefore, the sounders make a negligible contribution to the total RFR and are not given further consideration.

A.8 System Parameters

The characteristics of the OTH-B radar system described in this appendix were obtained from the OTH-B program office, Hanscom Air Force Base, Massachusetts (Snyder, 1982) and recently reconfirmed (Stevenson, 1986). These characteristics are listed in Table A-3.

Under typical operating conditions, the two arrays of the transmitting antenna system radiate simultaneously and continuously, usually on different frequencies. Each array is capable of radiating as much as 1.2 MW. However, each radiated power can be reduced in 1-dB (20%) steps by as much as 15 dB. Thus, the power radiated by each array may be as small as 37 kW. The power used for each 7.5° surveillance sector is independently chosen to optimize system performance. Consequently, the total power being radiated at any instant may vary from 148 kW to 4.8 MW, but will rarely approach either limit.

Table A-3

PARAMETERS OF THE OTH-B RADAR SYSTEM
(per array)

System Characteristics	Value
Continuous wave power	
Maximum	1.2 MW
Minimum	37 kW
Antenna gain, mainlobe maximum[a]	
Ratio	160
Decibels	22
Antenna gain, sidelobe maximum[b]	
Ratio	8
Decibels	9
Antenna gain, backlobe maximum[b]	
Ratio	1.6
Decibels	2
Half-power beam width	8.4°
Dwell time, each azimuth, maximum (s)	10
Revisit time, maximum (s)	80

[a]All gain figures are stated relative to an isotropic distribution (uniform in all directions) and represent an average value over the operating frequency band.

[b]The term "sidelobe" is used here to refer to any radiation in front of the backscreen other than the mainlobe, whereas "backlobe" denotes any radiation behind the backscreen.

Each antenna array scans an azimuth sector of 60° in increments of 7.5°. Each array contains 6 subarrays, each consisting of 12 similar dipole radiators; in each array, only 1 of the 6 subarrays operates at a given time, the choice depending on the frequency to be used. Normally, the 12 dipoles are allotted equal amounts of power; in some cases, better results are obtained by reducing the power delivered to some dipoles, which reduces the relative intensity of the sidelobes.

The maximum power density for sidelobes shown in Table A-3 is a factor of 20 smaller than the maximum power density in the mainlobe, and the backlobes (antenna lobes radiating behind the backscreen) have a maximum power density a factor of 100 smaller than the mainlobe maximum.

A.9 References

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Appendix B

CALCULATION OF RADIOFREQUENCY RADIATION INTENSITIES

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SYMBOLS AND UNITS OF MEASUREMENT

A	Area of array face
C	Velocity of light = 3×10^8 m/s
D	Effective length of each array
E	Electric field intensity (volts/meter)
F	Midband frequency of each array (MHz)
f	Frequency (hertz)
G	Antenna gain (ratio)
H	Effective height of each array
Hz	Hertz
J	Skin depth (meters)
K	Dielectric constant
L	Wavelength = C/f
m	Meters; milli (as a prefix)
N	Attenuation (nepers/meter)
P	Radiated power (watts)
R	Distance from point to array backscreen (ft)
R_s	Surface resistance (ohms)
S	Siemens
s	Seconds
S_b	Conductivity of vegetation
S_g	Conductivity of ground
μ	Magnetic permeability = 1.26×10^{-6} henry per meter
U	Power density (mW/cm^2)
V	Volts
W	Watts
Z	Azimuth from boresight direction (degrees)
π	3.1416

Appendix B

CALCULATION OF RADIOFREQUENCY RADIATION INTENSITIES

B.1 Introduction

In this appendix, an analytic procedure for calculating the intensity of radiofrequency radiation (RFR) in the vicinity of the OTH-B radar is developed. Data obtained from the OTH-B Program Office (Snyder, 1982; Stevenson, 1986), and the General Electric Company (Scott, 1982) are combined with information available in textbooks and technical journals to develop mathematical expressions that permit calculation of RFR intensity at specific locations. The first six sections are devoted to analysis; the remaining sections use the resulting analytic expressions to determine values for the maximum electric field intensity, maximum power density, and average power density at selected points in the vicinity of the radar. Power densities at the center of the beam are also calculated to provide a basis for estimating their effect on the personnel and electronic systems in aircraft and on birds.

This analytic technique allows predictions that are quite accurate in free space; however, the results are affected by the presence of the ground and of objects such as trees, buildings, and power lines. In the real world, the ground terrain is irregular, and objects such as trees, power lines, and other structures are randomly distributed. When they block the line of sight to the antenna, they tend to absorb, reflect, and scatter the field. In such circumstances, the strength of the field is lower than it would be in free space. In other situations, the power reflected from the earth or other objects adds to that propagated directly, thus increasing the intensity of the radiation. Under circumstances relevant to the OTH-B radar, the electric field strength is rarely as much as doubled in this way. Field enhancement of this kind is much more important in calculations of maximum electric field strengths and power densities than of time-averaged power densities.

Power density information is presented for two cases of interest: along the axis of maximum power density of the mainlobe, and along the ground directly below that axis. Depending on the transmission frequency, the axis is elevated approximately 12° to 22°, and the mainlobe extends approximately $\pm 4°$ in azimuth and $\pm 12°$ in elevation about the axis. Radiation near the axis comprises the so-called "space" or "sky wave." It is relatively unaffected by the properties of the earth in the vicinity of the transmit antenna array. Radiation along the ground below the axis comprises the so-called "surface" or "ground wave." The ground wave is strongly affected by the conductivity and dielectric constant of the ground. The situation is complicated by the fact that soil in Alaska is frozen during a substantial fraction of each year.

For points outside the 120° surveillance zone, the power density for both space and ground waves is derived from that of the mainlobe and its known relationship to backlobes and sidelobes.

This appendix develops power densities and other characteristics for a single 60° sector. It also considers array configurations in which beams from different arrays overlap. The validity of calculations based on these methods was confirmed by measurements made in the four frequency bands of the Experimental Radar System (ERS) at Moscow AFS, Maine (see Section B.8.3).

B.2 System Description and Calculation Methods

B.2.1 Antenna Characteristics

Designing a single transmit antenna array to accomplish the objectives of the OTH-B radar throughout the entire band of frequencies needed (5 to 28 MHz) is impractical. Consequently, in each face six separate antenna subarrays are employed, but only one is driven at any given time.

The six subarrays of each antenna face are aligned over a common groundscreen as shown in Figure B-1; each subarray serves the specific band of frequencies listed in Table B-1. Both the groundscreen and backscreen are constructed of copperweld or alumiweld wire mesh. The width (smaller dimension) of the groundscreen is 750 ft; the length is roughly 5,000 ft. The height of the backscreen varies from band to band, as shown in Table B-1. The length D of each array is taken as equal to six times the geometric mean wavelength L. This value differs slightly from the physical dimension but is sufficiently accurate for calculating RFR. Except for band F, the band-edge and midband frequencies follow a geometric progression with a ratio of 1.35.

Each subarray consists of 12 elements, uniformly spaced in a plane in front of and parallel to a vertical conducting backscreen. The radiating elements of bands E and F are vertical and produce only vertically polarized radiation; that is, the electric vector is vertical. The elements of the other bands are inclined at an angle of 45 deg and produce equal components of horizontal and vertical polarization.

Because of its configuration, each array produces a radiation field concentrated in a fan-shaped beam, narrow in azimuth, wider in elevation. The azimuth of the mainlobe axis is steered $\pm 30°$ from the direction perpendicular to the backscreen by varying the phase (timing) of the signals fed to the 12 elements of the subarray that is in use. In any phased array, the projected area A varies as the cosine of the scan angle. The gain varies directly, and the horizontal beamwidth inversely with A. In the OTH-B system, the scan angle varies from 0° to 30°, with cosine values of 1.0 and 0.87, respectively. Thus, the gain and horizontal beamwidth are nearly constant throughout the sector scanned.

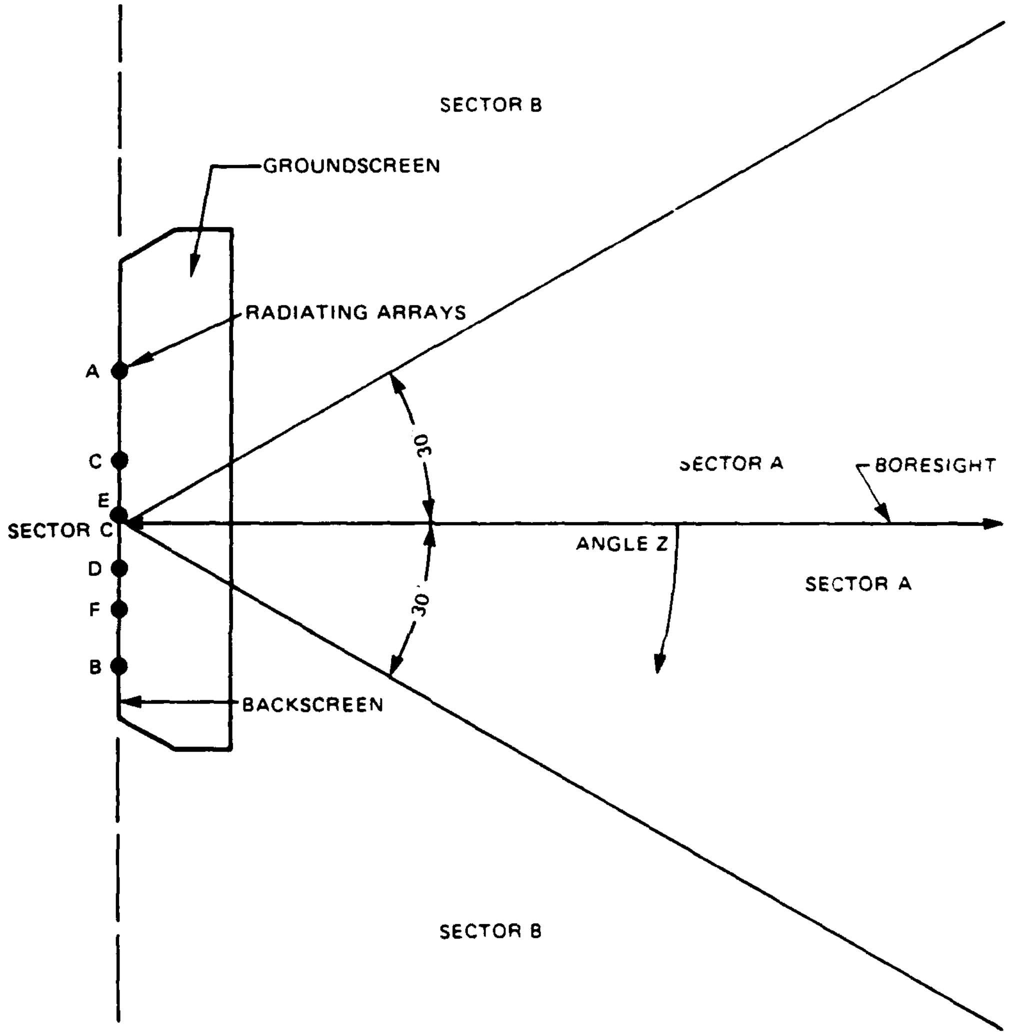

FIGURE B-1 SPACE SUBDIVISIONS USED FOR CALCULATION OF RFR (BAND E USED FOR EXAMPLE)

Table B-1

CHARACTERISTICS OF AN/FPS-118 ANTENNA ARRAYS

Band	Frequency Range (MHz)	Midband Frequency, F (MHz)	Midband Wavelength, L ft	Midband Wavelength, L cm	Array Length, D ft	Array Length, D cm	Backscreen Height (ft)
A	5.00-6.74	5.81	170	5,163	1,020	31,090	135
B	6.74-9.09	7.83	126	3,831	756	23,043	100
C	9.09-12.25	10.55	93.3	2,843	560	17,067	75
D	12.25-16.50	14.22	69.3	2,110	416	12,600	55
E	16.50-22.25	19.16	51.4	1,566	308	9,390	45
F	22.25-28.00	24.96	39.4	1,201	236	7,193	35

The resulting electromagnetic field (called RFR) of the main beam is normally described by dividing it into two regions, the near field and the far field, to which different sets of analytical conditions apply (Hansen, 1964). The boundary between the two regions is not sharply defined; rather, RFR conditions gradually change with increasing distance from the face of the antenna. Regions within or near the main beam and those at angles remote from it must also be distinguished. Different approximations apply to the different regions.

B.2.2 Frequency Bands and Radiation Zones

Because the ratio of the maximum to the minimum frequency in each band is not large, calculations based on the geometric mean frequency of each band have satisfactory accuracy for all frequencies in that band. All subsequent calculations are based on this assumption. For convenience, the mean wavelength L and the array length D are given in both feet and centimeters.

For directional antennas such as those of the OTH-B system, it is convenient to make a further distinction on the basis of azimuth, as shown in Figure B-1. Sector A, which extends ±30° from the array boresight (i.e., the direction its points), is the scan range of the main beam of the array that is operating. Maximum values of RFR are found in this sector. The B Sectors extend from 30° to 90° on either side of the boresight. These sectors are subject to first- and higher-order sidelobes of the main beam and receive intermediate levels of RFR. Sector C covers 180° behind the backscreen; it is subject to the lowest values of RFR, which are associated with backlobes of the array.

In the following sections, the letter Z is used to designate the angle between a particular location and the boresight direction of the applicable array.

The far field is defined as a region over which the analytical conditions are constant and the fields vary inversely with distance (i.e., the power density varies inversely with the square of the distance). The distance from the array center beyond which the far field exists is conventionally taken as 2 D^2/L. However, far-field formulas give satisfactory approximations for all distances greater than a transition distance of 0.18 D^2/L.

B.2.3 Conditions and Assumptions

An antenna that is large compared to a wavelength produces a radiation field that is concentrated in a relatively small volume of space. The OTH-B transmit antenna array falls into this class. The characteristics of such a beam radiation field are determined by the following features of the array:

- Shape
- Dimensions in wavelengths
- Power distribution
- Overall efficiency.

The mathematical description of the complete field produced by large antennas is complicated. Therefore, approximate expressions have been developed to facilitate calculation. The following conditions and assumptions are applied:

(1) The array is treated as a vertical rectangular aperture with horizontal width D, height H, and area A = DH.

(2) The main beam and sidelobes are assumed to have the intensities and distributions associated with a uniformly spaced 12-element array with equal currents in all elements (Silver, 1949).

(3) The transition between near-field and far-field conditions occurs at about 0.18 $D^2/L = 6.42$ L, because $D \approx 6L$.

(4) The maximum possible on-axis power density in the near field is assumed to exist throughout the near-field column.

(5) In most cases, the greatest possible field strength near ground level will exist when the antenna main beam is pointed toward the ground.

(6) The calculation of ground-level RFR field strengths at any distance up to 25 miles from the OTH-B transmit array is based on direct- or surface-wave propagation because all other modes of propagation are weaker. Ground-level areas that are

shadowed by intervening terrain will be illuminated by the diffraction mode of propagation. The RFR field strengths in such areas will be overestimated.

(7) Each array is treated separately; power addition is used to obtain RFR values in regions illuminated by more than one array.

(8) The width of the groundscreen is taken as 750 ft.

(9) Any mountain that rises sharply above ground level will be subject to values of RFR that are substantially higher than those calculated on the basis of surface-wave propagation. Upper bounds on the values of RFR that can exist at such locations are found by taking the maximum and average values of RFR that exist in the main-beam surveillance zone.

(10) The power radiated by the four sounders is small compared to that radiated by the main arrays and makes a negligible contribution to the total RFR.

B.3 Sector A

Sector A is of primary interest because it represents the range of azimuth angles scanned by the main beam and thus receives the highest levels of RFR. As previously noted, this sector must be further subdivided according to the elevation angle and the distance from the array.

B.3.1 The Far Field Region--Maximum Power Density

The far field is defined as a region over which the analytic conditions are constant and the fields vary inversely with distance. If the groundscreen were of infinite extent, the far field would start at a distance of approximately $2\ D^2/L$. The OTH-B transmit system involves other considerations that make this distance unimportant.

B.3.1.1 The Main Beam

A well-known and generally applicable equation for the power density on the beam axis in the far-field region of any antenna is

$$U = PG/4\pi R^2 \tag{1}$$

where U is the power density, P is the radiated power, G is the antenna gain, and R is the distance. Consistent units must be used. For the

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*Use of this value leads to maximum possible values of RFR. Substantially lower values of RFR will exist whenever lower power levels are used.

AN/FPS-118 system, P = 1.2 MW* and G = 160. To obtain results in the desired form of mW/cm^2 when the range is specified in feet, it is necessary to introduce suitable factors. To convert from megawatts to milliwatts and from square feet to square centimeters, it is necessary to multiply by 10^9 and divide by $30.48^2 = 929$. Combination of these various terms leads to a key result: for all six bands the far-field maximum power density U_1 in the center of the main beam is given by

$$U_1 = 16.5 \times 10^6/R^2 \quad mW/cm^2 \tag{2}$$

where R is the distance in feet. This is an important relationship, but its usefulness for calculating ground level power densities is limited for reasons that are given in the following sections.

B.3.1.2 The Far Field Region--Average Power Density

The principal function of the ARS is to detect aircraft and cruise missiles approaching Alaska. To provide the needed surveillance, the transmitted beam is stepped in increments of 7.5° through the 60° azimuth range allotted to a particular array. The total (null to null) width of the main beam is about 19°; however, the effective width (measured to the half-power relative intensity points) is only 8.4°. Thus, the time-averaged power density U_2 at any given distance is 8.4/60 = 0.14 times the maximum power density in the mainbeam. Hence, from equation (2),

$$U_2 = 0.14\ U_1 = 2.3 \times 10^6/R^2 \quad . \tag{3}$$

This relationship, which applies to all six bands, is valid only in sector A and is subject to restrictions on R that are developed in subsequent sections. It neglects any contributions made by sidelobes that sweep through the sector.

B.3.2 The Near-Field Region

B.3.2.1 Maximum Power Density

For the main lobe of an antenna array, idealized as a rectangular aperture, the maximum power density values on and near the beam axis in the near-field region can be calculated by a method similar to that of Hu (1961). The gain G of an antenna is related to its effective aperture area A by the equation

$$G = 4\pi A/L^2 \text{ or } A = GL^2/4\pi \ . \tag{4}$$

The aperture area A of the array is equal to its width D times its effective height H. As shown in Table B-1,

$$D \approx 6L \quad . \tag{5}$$

Substitution of these relationships and G = 160 in equation (4) yields

$$H = 2.12\ L \quad . \tag{6}$$

The total radiated power P must pass through the area A. Thus, the average power density near the face of the array is equal to P/A. In the near-field region the power density is very uneven. In some places the fields are quite weak; in others, the field strengths are doubled, and the power density is 4 times as large as its average value. On this basis, the maximum power density U_o near the array on and near the beam axis is taken as

$$U_o = 4P/DH = 0.31P/L^2 \quad . \tag{7}$$

This quantity is given in mW/cm^2 if P is stated in milliwatts and L is the wavelength in centimeters. In the present situation $P = 1.2 \times 10^9$ mW; using this value and dividing by $(30.48)^2 = 929$ to convert from centimeters to feet yields

$$U_o = 4.0 \times 10^5/L^2 \quad . \tag{8}$$

This value is used as representative of the maximum power density existing within the roughly rectangular near-field column.

B.3.2.2 <u>The Near-Field Extent</u>

Equations (2) and (8) apply to different regions. They give equal values at a particular distance R_o, where

$$U_o = U_1 = 4.0 \times 10^5/L^2 = 16.5 \times 10^6/R_o^2 \tag{9}$$

which yields

$$R_o^2 = 41.25\ L^2, \text{ or } R_o = 6.42\ L \quad . \tag{10}$$

Because $D \simeq 6L$, the ratio D^2/L is given by

$$D^2/L = 36L \quad . \tag{11}$$

Thus

$$R_o = 0.18\ D^2/L \quad . \tag{12}$$

This value is used as a convenient outer limit of the near-field region. Equations (8) and (10) were used to prepare Table B-2, which shows the extent and power densities of the near-field regions of the six arrays.

Table B-2

NEAR-FIELD DISTANCES AND POWER DENSITIES FOR OTH-B ARRAYS

Band	Wavelength, L (ft)	Distance, R_o (ft)	U_o (mW/cm^2)	R_1 (ft)
A	170	1,091	13.84	1,020
B	126	809	25.2	756
C	93.3	599	46.0	560
D	69.3	445	83.3	416
E	51.4	330	152	308
F	39.4	253	258	236

Key:
U_o = Maximum power density in near-field column
R_o = End of near-field region
R_1 = D ≃ 6L

B.3.2.3 Average Power Density

Consistent with the width of the array, the near-field column is quite wide and does not move much as the beam is stepped from side to side. Therefore, near the face of the array, the average power density is only slightly affected by beam motion. However, the average value throughout this region is only one-fourth of U_o. The effect of beam motion increases with increase of the distance from the array center (see Figure B-2). At the distance $R_1 \doteq D$, the length of the arc swept by the beam is approximately twice the length of the array; hence, at this distance the average power density is reduced by half from $U_o/4$ to $U_o/8$. Because this value does not differ significantly from the value U_2 - 0.14 U_1 at the same distance, it is legitimate to use U_2 to represent the average power density for all distances greater than R_1 (which does not differ substantially from R_o). At smaller distances, the average power density becomes irregular with local "hot spots" having values as high as U_o. In the charts described in Section B.6, this effect is accounted for by using U_2 down to the distance at which its value is equal to U_o.

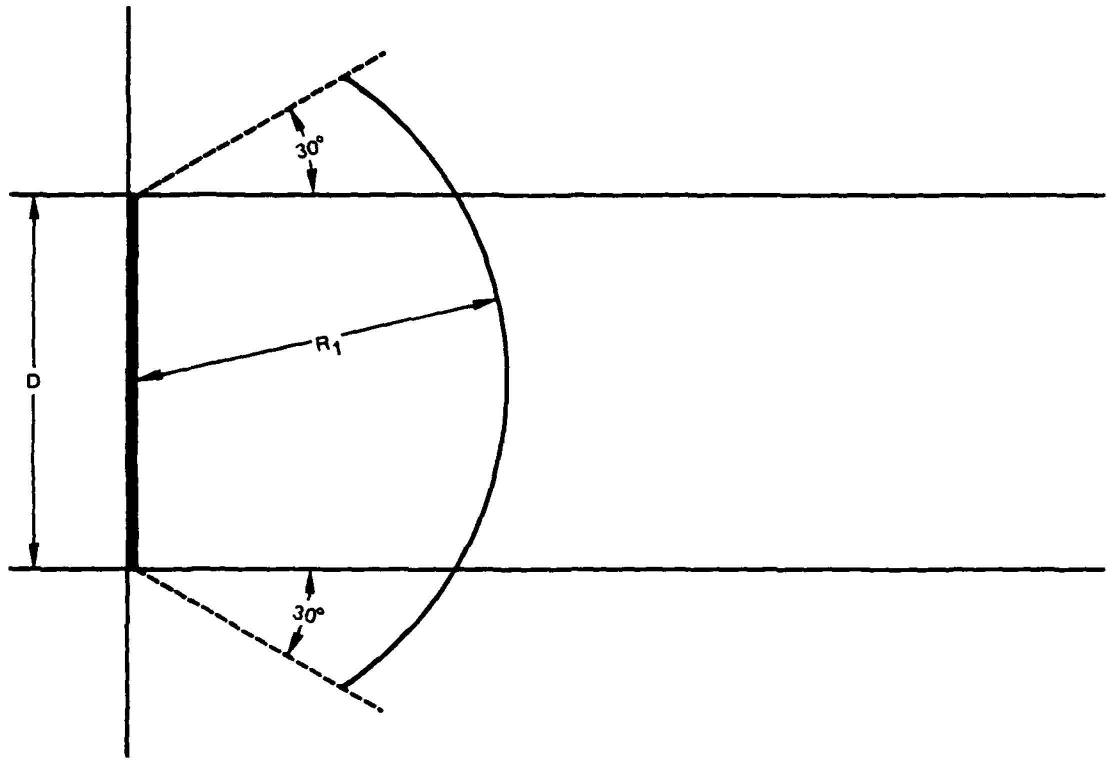

FIGURE B-2 VARIATION OF AVERAGE POWER WITH DISTANCE

B.3.2.4 Effect of the Earth

When a radio wave traveling in air strikes another material such as metal or soil, part of the energy is reflected and part is transmitted into the material. Metals are good reflectors, but the ground accepts a substantial fraction of the incident energy. The nature of the wave in the ground and the distance that it penetrates depend on the frequency and the properties of the ground. The behavior of the wave is governed by the ratio of the ground conductivity S_g to the product $2\pi fK$, where f is the frequency and K is the (absolute) dielectric constant. The conductivity of the ground varies widely; that of the soil in Alaska varies substantially with the season, with reported values ranging from 10^{-4} to 0.12 siemen/meter (S/m).* The former applies to frozen earth (permafrost); the latter to wet soil during summer months. The dielectric constants of different soils are also variable.

*The unit of conductance, formerly called the mho, is now the siemen. For comparison, the conductivity of sea water is about 4, and the conductivity of copper is 58,000,000.

For soils in the vicinity of the ARS transmit arrays, the conductivity is the dominant parameter, and the value of the dielectric constant is unimportant. Under these conditions, the wave within the soil travels by diffusion rather than propagation. The key parameter is the skin depth, which is the distance penetrated by the wave before its intensity falls to 1/e = 0.37 of its initial value. This distance J is given by Ramo and Whinnery (1953) as

$$J = (\pi f \mu S_g)^{-1/2} \text{ meters} \tag{13}$$

where μ is the magnetic permeability (about 1.26×10^{-6} henry per meter (H/m)). For applicable values of ground conductivity, the value of J is approximately one meter. The essential fact is that the earth will absorb and dissipate power from electromagnetic waves that are propagated over or near its surface.

Because the ground is not a perfect conductor (i.e., reflector), it absorbs power and reduces the intensity of electromagnetic waves near its surface. For the far-field distances of interest, the effect of ground attenuation is to add a term of the form R^4 in the denominator of the equation that relates power density to distance. The coefficient that multiplies R^4 determines the distance at which the variation of power density versus distance makes a transition from $1/R^2$ to $1/R^4$; the transition distance varies with the conductivity of the ground and the frequency used. In the present case it is always larger than 750 ft because of the groundscreen.

A complete analysis of the propagation of radio waves near the surface of the ground is complicated (Norton, 1941). For present purposes, it is sufficient to determine the transition distance R_2. This is the point at which the dimensionless parameter, called the numerical distance, commonly used in such calculations, has the value 1/2. Equations developed by Norton can be combined to yield

$$R_2 = 2.9\, L^2\, S_g \tag{14}$$

where L is the wavelength in feet, S_g is the conductivity of the ground, and R_2 is the distance in feet at which the transition occurs. During summer in Alaska, the ground is very wet, and conductivity values are high. Applicable values for the dielectric constant and conductivity of "marsh land or rice paddies" are taken from a publication of NOSC (D.B. Sailors et al, 1983).

Their results are expressed by the equation,

$$S_g = 0.1115\, F^{0.106};\; K = 9.76 \times 10^{-10} F^{-0.417} \tag{15}$$

where F is the frequency in MHz, and K is the absolute dielectric constant. Values of dielectric constant, conductivity, and skin depth were calculated from these equations and equation (14) and used to develop the set of values presented in Table B-3.

Table B-3

NUMERICAL DISTANCES AND OTHER VALUES FOR OTH-B ARRAYS

Band	A	B	C	D	E	F
F (MHz)	5.81	7.83	10.55	14.22	19.16	24.96
L (ft)	170	126	93.3	69.3	51.4	39.4
S_g (s/m)	0.134	0.139	0.143	0.148	0.152	0.157
R_2 (ft)	11,230	6,400	3,610	2,060	1,160	700
R_3 (ft)	11,980	7,150	4,360	2,810	1,910	1,450
K (10^{-10}f/m)	4.68	4.14	3.65	3.22	2.84	2.55
J (m)	0.57	0.48	0.41	0.35	0.29	0.25
$2\pi fK/S_g$	0.13	0.15	0.17	0.19	0.22	0.25

In this table, R_2 is the range at which the "numerical distance" = 1/2, and R_3 is the distance (which is 750 ft greater than R_2) at which $1/R^4$ propagation begins. This increment represents the width of the groundscreen, which prevents main beam absorption. The final line of Table B-3 shows that the ratio $2\pi fK/S_g$ is always smaller than unity. This fact justifies the use of equation (14).

In winter the ground freezes, and the conductivity decreases drastically to about 10^{-4} S/m. The dielectric constant also decreases, but not to the same extent. As a consequence of these changes, the radio waves penetrate the ground much more deeply, and the attenuation of the wave near the earth is greatly increased. The applicable equations are much more complicated than those used above. They lead to values of R_2 and R_3 that are considerably smaller than those shown in Table B-3 and are therefore unimportant for this document.

Ground-level power densities are further affected by the orientation of the dipole array elements. Bands E and F use the vertical orientation, to which the statements in the preceding paragraph directly apply. However, the elements of the other bands are oriented at 45° from the vertical. In effect, half the total power can be considered to be radiated with vertical polarization and half with horizontal polarization. The horizontal component is effectively suppressed at ground level because of the conducting groundscreen and earth (Norton, 1941). Hence, for bands A, B, C, and D, the ground-level power density is further reduced by 50% at all distances of interest.

With these considerations and the free space power density expressions, the maximum power densities at ground level in sector A can be calculated.

B.3.2.5 <u>Effect of Vegetation</u>

It is known that tropical jungles produce strong attenuation of signals in the 5- to 28-MHz band, and a considerable amount of data exists for jungle propagation. No data directly applicable to the present situation have been found. The following paragraphs develop a basis for estimating the effect of trees or brush that may be found in the vicinity of the ARS transmit arrays.

We proceed by considering a 1 m^2 portion of a vertically polarized electromagnetic wave traveling along the surface of the earth at a frequency f corresponding to a wavelength L. The effect of vegetation is accounted for by considering the region to have a modified (complex) dielectric constant $K = K' + jK''$, where $j = (-1)^{1/2}$ (Ramo and Whinnery, 1953).

For a wave propagating along the surface under these conditions, the attenuation N (in nepers* per meter) is given by the equation

$$N = \pi K''/LK' \quad . \qquad (16)$$

The ratio K''/K' is commonly called the loss tangent of the material; in the present situation, it is given by the equation

$$K''/K' = S_b/2\pi f K_o = L\ S_b/2\pi C K_o \qquad (17)$$

where S_b is the effective conductivity of the air/vegetation mix, f is the frequency (in Hz), $C = 3 \times 10^8$ is the velocity of light, and $K_o = 8.8 \times 10^{-12}$ is the dielectric constant of free space.

For typical forest environments, the value of S_b is about 10^{-4} (Tamir, 1967). A value of $S_b = 10^{-5}$ is chosen here as representative of the more sparse vegetation typical of the region of the ARS transmit arrays. Use of this number with equations (16) and (17) yields N = 0.0019 Np/m, which is independent of frequency.

It is instructive to compare this value with the attenuation caused by imperfect soil conductivity. A convenient formula (Ramo and Whinnery, 1953) is $N = R_s/757$, where $R_s = (\pi f \mu/S_g)^{1/2}$ is the surface resistance of the earth. In this expression, $\mu = 1.26 \times 10^{-6}$ H/m is

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*One neper (Np) corresponds to a reduction of the electric field intensity by a ratio of 2.718, or 8.68 dB.

the magnetic permeability of free space and S_g is the ground conductivity. This expression applies to a plane-parallel wave guide system 1-m high in which the upper conductor is perfect, whereas the lower conductor has the finite conductivity S_g. Substitution of f = 10 MHz and S_g = 0.16 S/m in this equation yields N = 0.021 Np/m.

The important conclusion to be drawn from the foregoing comparison is that, even for highly conducting soil, the attenuation due to the earth is large compared with that produced by a credible distribution of vegetation. Thus, attenuation caused by vegetation can be dismissed from further consideration. This statement is based on the assumption that no large trees will be tolerated within the exclusion fence.

B.3.2.6 Beam Overlap

The beam of each array is stepped through a total angle slightly less than ±30° in such a way that the average power density, U_2, remains substantially constant across the boundaries ±30° from the boresight of each array. If the two antenna arrays are configured so that no beam overlap occurs, maximum and time-averaged power densities are essentially constant over the full 120° angular range both at ground level and throughout the surveillance zone. If the two antenna arrays are arranged so that substantial beam overlap occurs in the region close to the antenna faces, the overlapping beams do not interact, but the average power density in this region is enhanced.

B.4 Sector B

On each side of the sector scanned by the main beam, one sector is exposed only to sidelobes. For each array these sectors are bounded by the values Z - ±30° and Z = ±90°. The levels of RFR in these sectors are substantially lower than those in sector A. A procedure for calculating these levels is developed in the paragraphs that follow. As noted in the following section, the power densities in the range Z = ±50° to Z - ±90° do not exceed those in sector C. Therefore, these regions are merged into sector C.

B.4.1 The Sidelobes--Maximum Power Density

The power densities in the main beam and sidelobes of a uniform 12-element subarray with uniform amplitude and phase are shown in Figure B-3 (Silver, 1949). The maximum intensity of the first (right and left) sidelobes is about 1/20 and the maximum intensity of the most remote sidelobes is about 1/150 that of the main beam. For consistency with the backlobe level specified in Appendix A, we use 1/100 as the lower limit for all sidelobes.

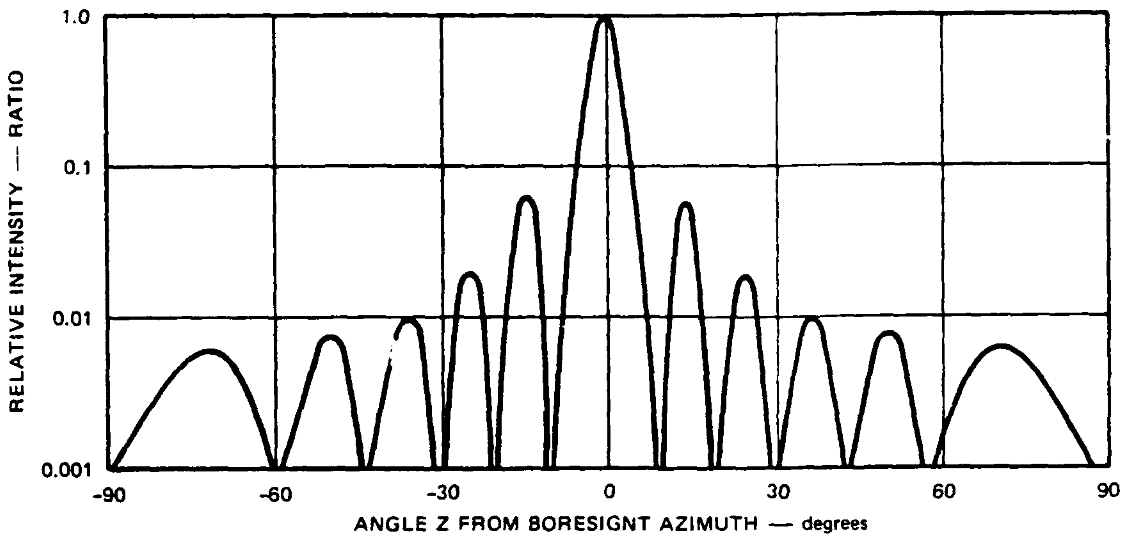

FIGURE B-3 FAR-FIELD PATTERN FOR 12-ELEMENT ARRAY

During the normal beam stepping process, the main beam deviates about ±30° from its boresight position. The first sidelobes follow most of the motion, but the more remote sidelobes are less mobile. Figure B-4 shows the approximate form of the far-field pattern when the beam is deflected through the maximum scan angle of 30°. Only the first and second sidelobes are found in the region 30° to 50°, and their maximum values are well approximated by the sloping straight line shown. As previously noted, the value 0.01, corresponding to 1/100 of the maximum value, is used in the 50° to 90° region.

The foregoing procedure is strictly valid only for the far field. However, the sidelobes do not benefit from the full area of the aperture, and the far-field criterion is satisfied at much smaller distances than for the main beam. Therefore, in the charts shown in Section B.6, the $1/R^2$ segment is continued down to R = 100 ft.

B.4.2 The Sidelobes--Average Power Density

The beam-stepping process, which produces a continual motion of the sidelobes as well as of the main beam, causes the average power density in the B sectors to be lower than the maximum density. Consistent with the values used in sectors A and C, this reduction factor is taken as 0.14. The validity of this value is clarified in Section B.5.2.

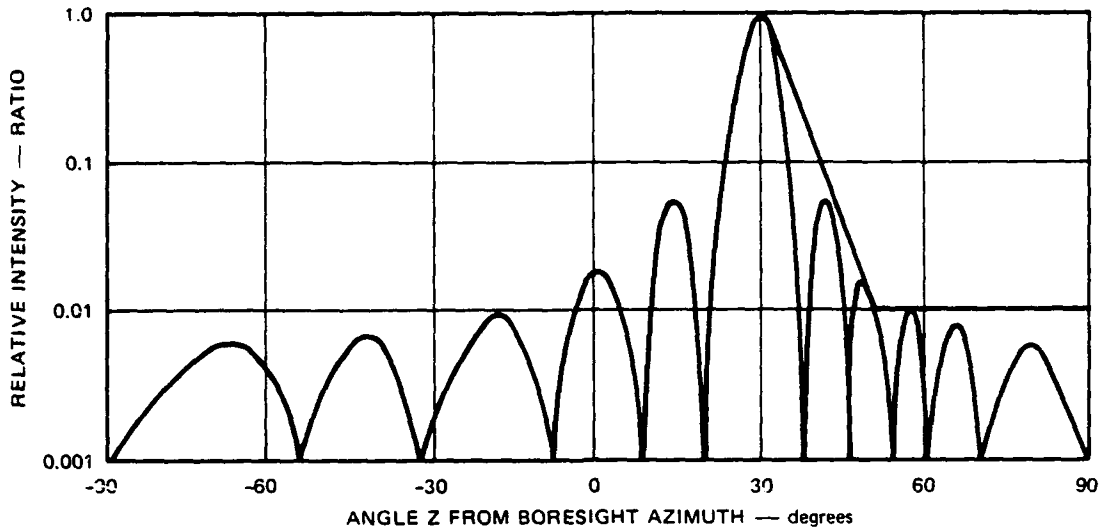

FIGURE B-4 FAR-FIELD PATTERN FOR 12-ELEMENT ARRAY — AT SCAN LIMIT

B.5 Sector C

B.5.1 Maximum Power Density

Sector C is the region where Z is greater than 90°, corresponding to locations entirely behind the backscreen. As noted in Table A-3, the maximum intensity in this sector is never greater than 1/100 that in the center of the main beam. Moreover, there is no groundscreen to reduce ground losses near the antenna. This information is sufficient for calculating maximum power densities throughout sector C.

B.5.2 Average Power Density

The distribution of power in sector C is nonuniform and changes with the scan angle of the various beams. Thus, average power densities are considerably lower than corresponding maximum values. Numerous measurements of the backlobe distribution of reflector-type antennas (Katz, 1979) indicate that such antennas have values of median absolute gain near -10 dB, that is, about 0.1. As noted in Appendix A, the maximum value of absolute gain in sector C is +2dB, or 1.6. Application of these values to the present situation would lead to a factor of 16 as the ratio of maximum to average power densities in sector C. To be conservative, and for consistency with sector A, we use the smaller factor 7 (or its reciprocal 0.14) to relate peak and average power densities in sectors B and C.

B.6 Preparation of the Charts

The preceding sections have developed expressions for calculating maximum and average power densities generated by the individual arrays. These results are now combined to describe the total radiation produced by all the subarrays of any single complete antenna array. The various sectors are identified in Figure B-1, with the understanding that the extent of sector B is reduced from 60° to 20°.

In the far field of sector A, the maximum and average power densities are both uniform for all values of Z less than 30°. In the B sectors, both maximum and average power densities in the far field decrease in an orderly manner as Z increases from 30° to 50°, at which point they become independent of Z and have magnitudes that are 100 times smaller than those in sector A.

B.6.1 Chart for Band F

The procedure used is illustrated in Figure B-5 for band F, which uses vertical dipoles. Reference to Table B-2 yields U_o = 258 mW/cm^2 and R_o - 253 ft. Starting at this point, a horizontal line is drawn to the left; it represents the maximum power density in the near-field column of the main beam. A line with a slope corresponding to $1/R^2$ is drawn to the right. At $R = R_3$ = 1,450 ft (taken from Table B-3), the sloping line branches. The continuing dotted segment represents the maximum power density in the elevated main beam. The dashed line starting down from R_3 = 1,450 ft represents maximum power density at ground level for S_g = 0.157 S/m; its slope corresponds to $1/R^4$ variation with distance.

Average power density is represented by solid lines parallel to those just identified. The separation represents a relative magnitude of 0.14. The upper line is continued to the left until it intersects the horizontal line that represents U_o. This intersection occurs near R - 100 ft. This construction completes the treatment of sector A.

We next turn to sector C, which corresponds to values of Z greater than 50° relative to the applicable face. The backlobes that represent RFR in sector C have a maximum intensity that is 1/100 that of the main beam and vary with time.

The conditions in sector C differ from those in sector A in two important respects: (1) there is no groundscreen; therefore, branching occurs at R_2 = 700 ft instead of R_3 = 1,450 ft, and (2) there is no orderly near-field column; therefore, the dashed line for maximum power density does not break at R_o = 253 ft. The lines representing average power density in sector C are parallel to those representing maximum power density and have a relative magnitude of 0.14.

Sector B corresponds to values of relative Z between 30° and 50°. Values of RFR in the B sectors are obtained by linear interpolation

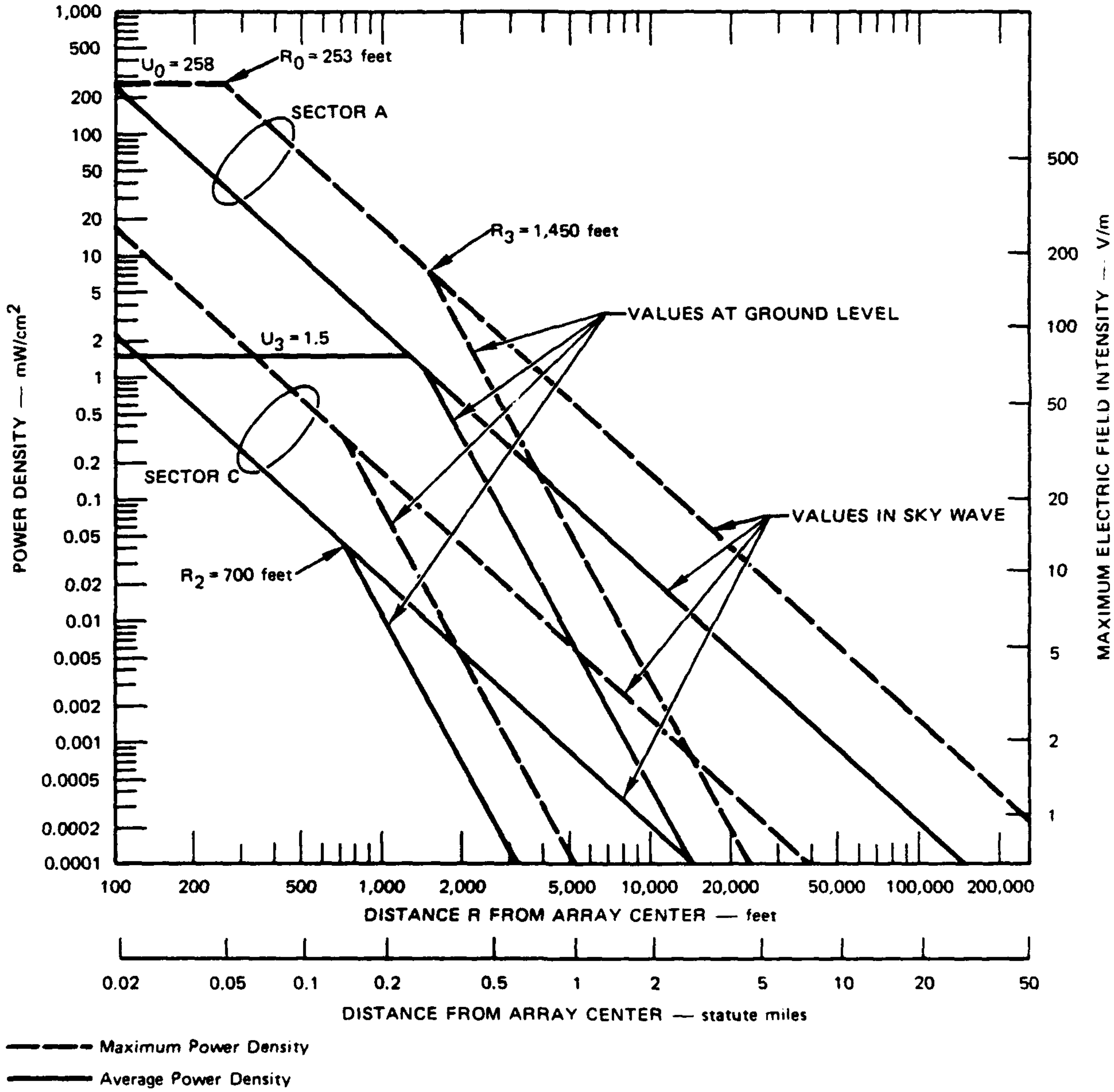

FIGURE B-5 RFR VALUES FOR BAND F

between those for sector A and sector C. For example, the maximum power density at an azimuth of 35° is found one-fourth of the way from the maximum power density line for sector A and that for sector C. A similar statement applies to the average power density in this sector. Linear interpolation (on logarithmic paper) is chosen because it is believed to give an accurate estimate of real-world values of RFR. This completes the construction of Figure B-5. Figure B-6 for Band E follows exactly the same procedure, the only differences being the numerical values of U_o, R_o, R_2 and R_3.

Bands A, B, C, and D use dipoles that are inclined at an angle of 45°; such dipoles radiate half their power with horizontal polarization. Only vertical polarization is sustained near a conducting surface such as that of the earth. Therefore, ground-level values of RFR--both maximum and average--are half as large as they would be if the dipoles were vertical. Figures B-7 through B-10 were prepared on this basis.

Figures B-5 through B-10 give RFR values directly for the ground conductivity values shown in Table B-3. Lower values of power density will exist whenever the conductivity values are lower.

B.6.2 Electric Field Intensities

For assessing hazards to electroexplosive devices (EEDs) and cardiac pacemakers, the electric field intensity corresponding to a given power density is needed. The electric field intensity E, given in V/m, may be calculated from:

$$E = (3{,}770\ U)^{1/2} \tag{18}$$

where U is the power density in mW/cm^2.

This relationship* is used to establish the scale along the right-hand edge of Figures B-5 through B-10. It is designated E_m to emphasize that it is applicable only to maximum values of intensity because average values of electric field have little significance.

B.7 Estimating Safe Distances

The most recent ANSI standard (ANSI, 1982) specifies power density limits that vary from 1 mW/cm^2 at 30 MHz to 36 mW/cm^2 at 5 MHz+. The applicable equation is

---

*This relationship is exact only in the sky wave, but it is a good approximation for all conditions of this EIS.

+The ANSI standard calls for time averaging over an interval not exceeding 6 min. This condition is met for all scan sequences of the OTH-B radar.

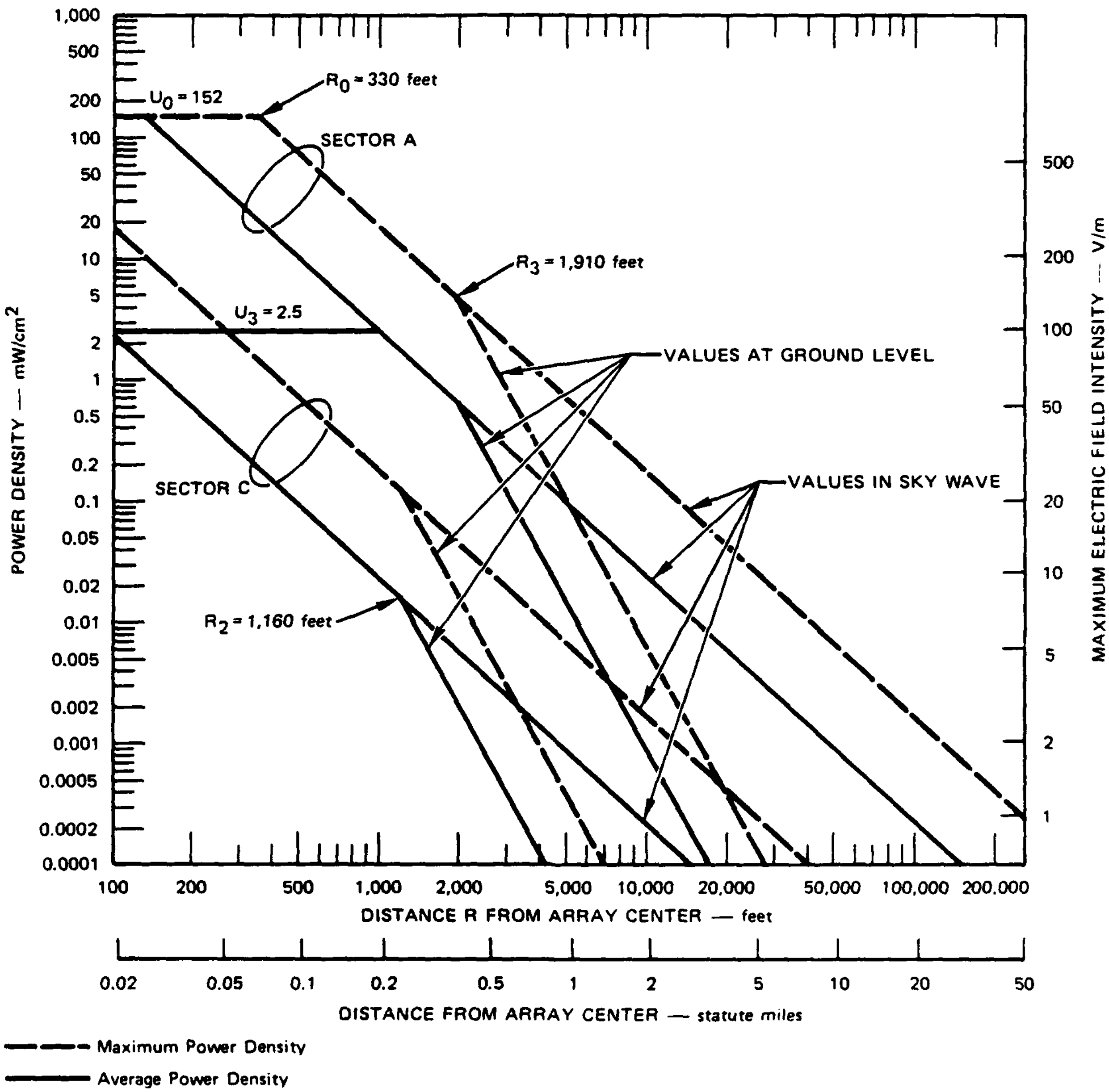

FIGURE B-6 RFR VALUES FOR BAND E

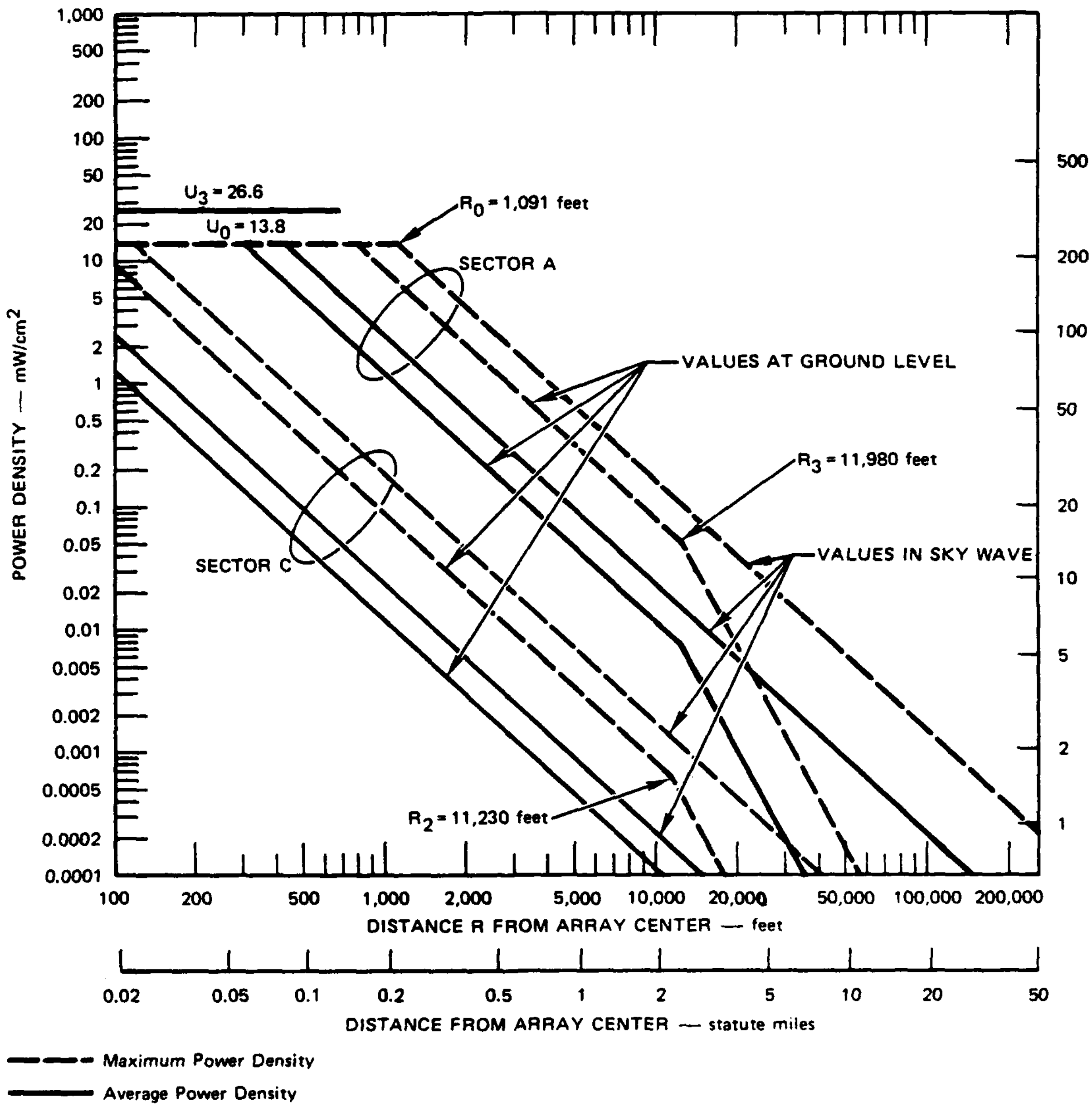

FIGURE B-7 RFR VALUES FOR BAND A

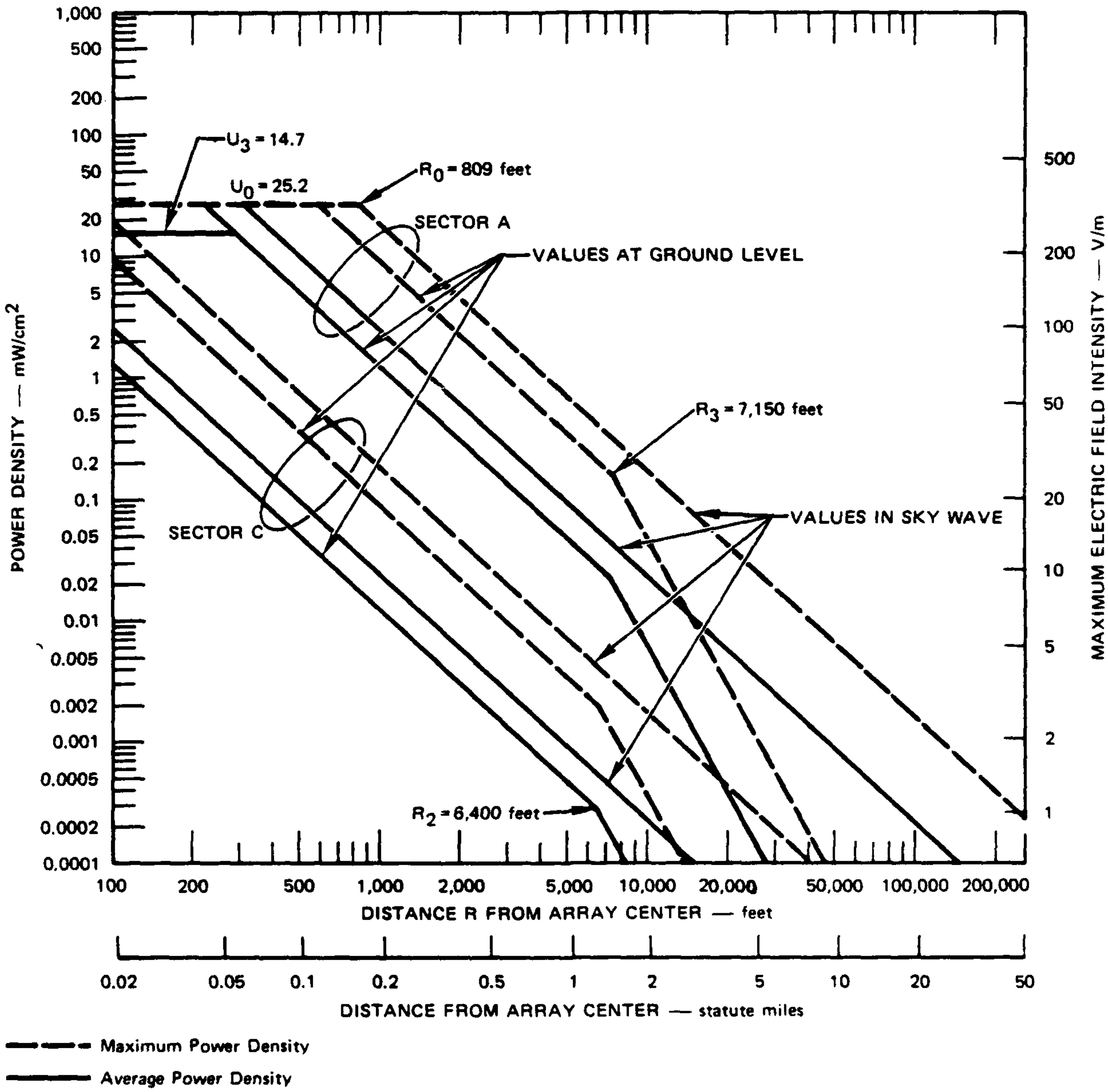

FIGURE B-8 RFR VALUES FOR BAND B

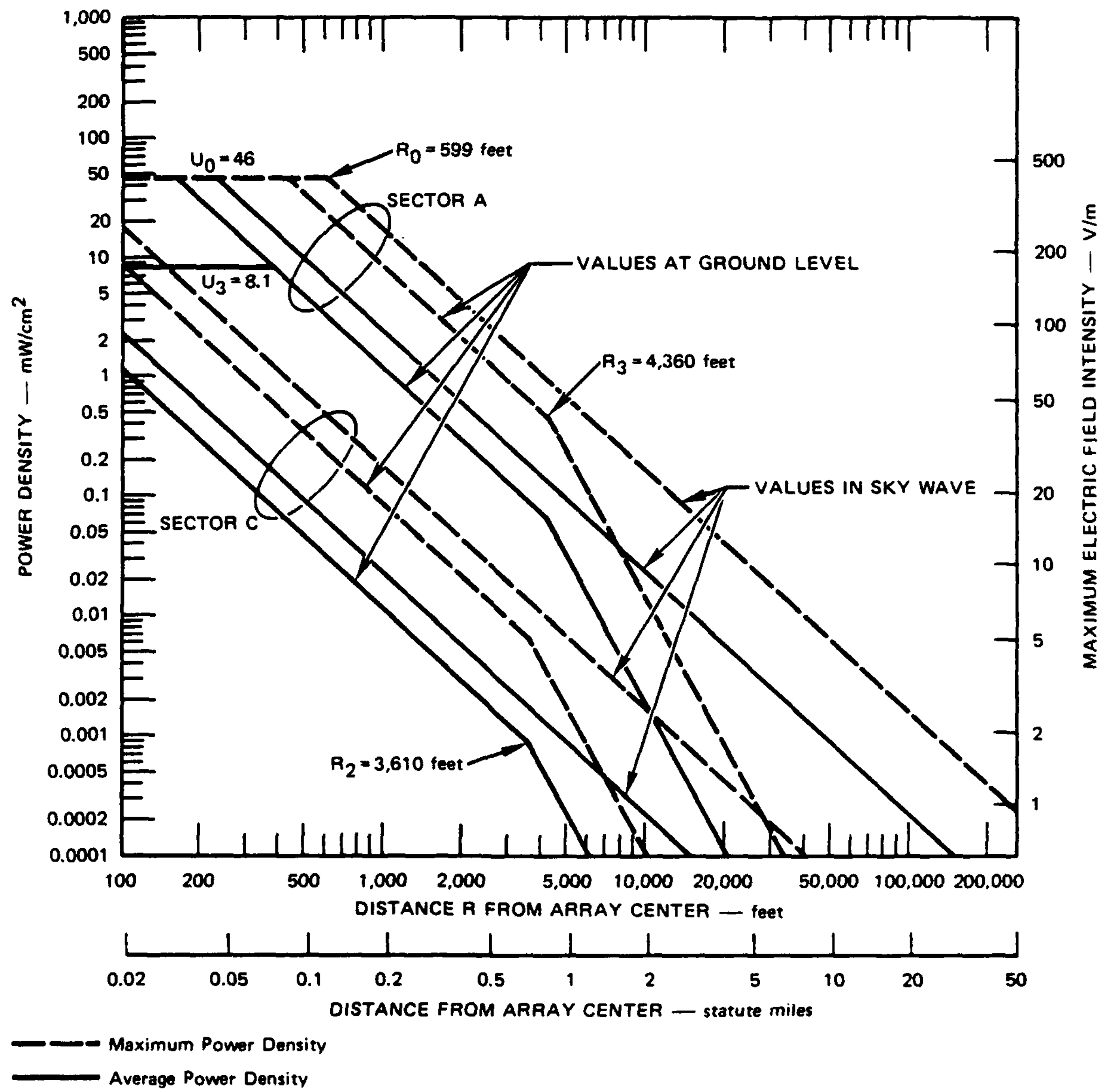

FIGURE B-9 RFR VALUES FOR BAND C

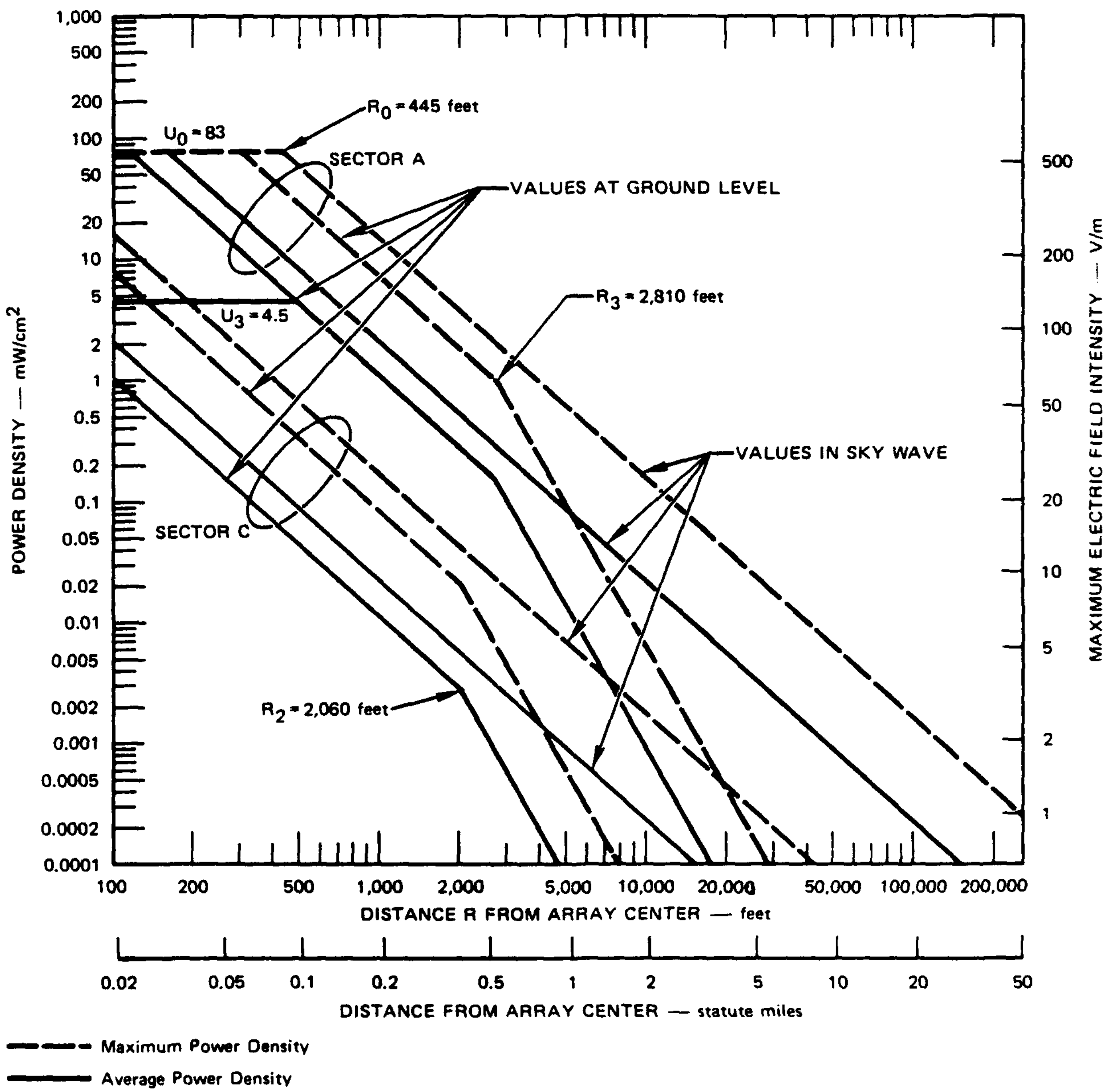

FIGURE B-10 RFR VALUES FOR BAND D

$$U_3 = 900/F^2 \qquad (19)$$

Values calculated from this equation for the mid-band frequency of each array are presented in Table B-4 and shown as horizontal lines in Figures B-5 through B-10. The intersections of these lines with the sloping average-power lines give the safe-distance values presented in Table B-4.

Table B-4

SAFE DISTANCES FOR OTH-B ARRAYS

	Band					
	A	B	C	D	E	F
$U - 900/F^2$	26.6	14.7	8.1	4.5	2.5	1.5
Sector A, ft		270	370	500	950	1,250
Sector C, ft		27	37	50	95	125

B.8 Validation

The validity of the methods used to derive the results presented in Figures B-5 through B-10 has been confirmed by comparing the results of similar calculations with measurements made on 9-10 June 1981, at the ERS transmitter site near Moscow, Maine, which included only a single antenna array with four transmitting subarrays. Because the ERS operated below the 1.2-MW power level of the proposed CRS, the measurements have been scaled up to indicate the levels that would have existed if the transmit power had been 1.2 MW. Only bands B, C, D, and E were operational and available for measurement.

The measurement locations are indicated by numbers 1 through 14 on Figure B-11. Positions 1 through 4 were about 10 to 15 ft inside the exclusion fence and about 2,400 ft in front of the antenna array centers for bands C, E, D, and B, respectively. Positions 5 through 8 were all about 5 to 10 ft outside the exclusion fence and alongside the access road. Position 9 was about 20 ft outside the fence and 3 ft in front of the plane of the backscreen; it was therefore behind the dipole elements of the array. Position 10 was at the same distance outside the fence, but situated in the same plane as the band-B dipole elements. Positions 11 through 14 were behind the centers of the antenna arrays about 5 ft outside the exclusion fence. For those points, the approximate distances from the backscreen were 110 ft for band B, 115 ft for band D, 40 ft for band E, and 115 ft for band C.

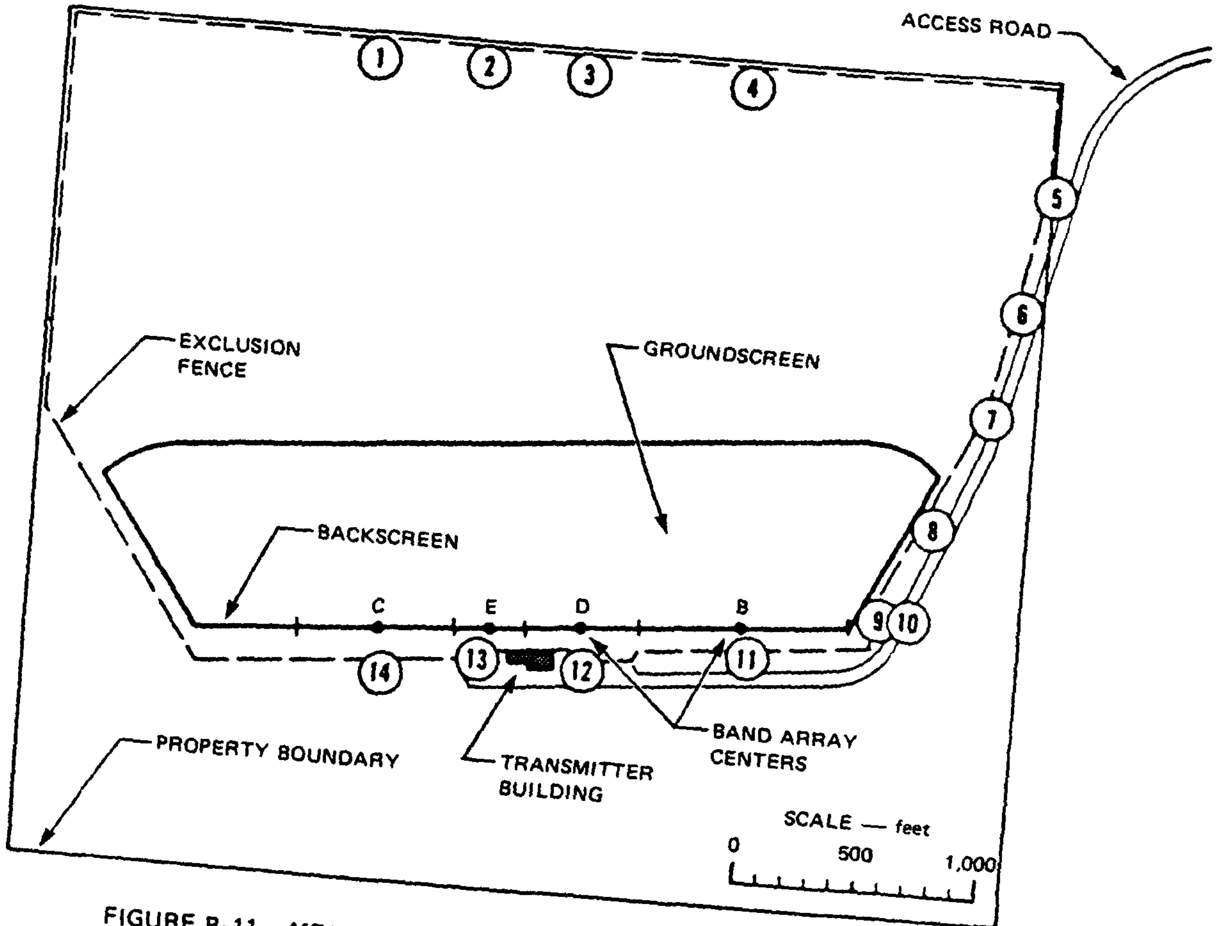

FIGURE B-11 MEASUREMENT LOCATIONS AT THE ERS TRANSMITTER SITE

Four transmitted frequencies were used--one near the center of each of the four bands. They were 7.83 MHz for band B, 10.55 MHz for band C, 14.54 MHz for band D, and 19.20 MHz for band E. The radar was operated in a CW mode at these fixed frequencies, instead of its usual FM mode. This procedure facilitated the accurate tuning of the measurement equipment while leaving the power density unaffected. The azimuth of the beam was stepped in increments of 4°; it was not swept continuously. Thus, the power density measurements correspond to maximum rather than average values.

B.8.1 Measurement Equipment

The measurement receiver was a Singer Model NM-26T Electromagnetic Noise Meter operating as a calibrated, tuned radiofrequency voltmeter. This battery-operated receiver has a bandwidth of about 3.6 kHz and is tunable over the range from 150 kHz to 32 MHz. It has an internal impulse generator for calibration at the frequency of measurement. Its rms detector was used so that true rms signal-level values were obtained.

The antenna was a Singer Model 92200-3 loop antenna, which includes its own matching network. The antenna, mounted on a wooden tripod at a height of about 4.5 ft, was connected to the receiver by a 6-ft length of RG-58/U flexible coaxial cable. Although such a loop antenna senses the magnetic field, the manufacturer's calibration curves allow the antenna's output voltage to be interpreted as the equivalent electric field anywhere within the far field of the source. Power density may be calculated from the electric and magnetic field strengths.

Communication between the measurement team and the operators of the radar was maintained by VHF handy-talkies.

B.8.2 Measurement Procedures

At each measurement location, the equipment was set up, and communication was established with the radar operators to tell them the desired frequency and beam-azimuth angle. The receiver was tuned to the appropriate frequency, which was verified by having the transmitter turned off and on. The loop antenna was then oriented for the maximum signal level. In most cases it was found that the maximum signal was received with the plane of the loop vertical and intersecting the midpoint of the antenna array; exceptions are discussed later. In this orientation, the horizontal magnetic field (vertical electric field) can be measured. Measurements were also made with the plane of the loop horizontal to sample the vertical magnetic field (horizontal electric field). A data sheet was used for each location to log details of the location as well as the meter readings and other pertinent data.

At the more remote locations (positions 1 through 4), heavy brush and sloping terrain made it difficult for the measurement team to determine when they were directly in front of the operating antenna arrays. To ensure that maximum power density was measured, the beam was deviated ±16° in azimuth in increments of 4°.

At positions 5 through 8, only band B was measured, and the beam azimuth was stepped from 30° right to 4° left while measurements were made again at 4° intervals.

All four bands were measured at position 9, although the beam was stepped only for the band-B measurements. At position 10, only band B was measured; the beam was steered to 30° right azimuth.

At positions 11 through 14 behind the arrays, the measurements were made with the associated transmitting antenna beams undeviated. The loop was oriented to maximize the level of the received signal.

The ground in the vicinity of the radar was very wet during the measurements, maximizing the soil conductivity and, hence, the values of power density near the ground. At some points, there was standing or running water to a depth of perhaps a foot.

The transmitter system was not operated at the full 1.2-MW output; the actual output power was recorded for each measurement frequency so that the measured signal levels could be adjusted upwards to determine the equivalent 1.2-MW output values.

B.8.3 Results

The horizontal magnetic field (vertical electric field) predominated over the vertical magnetic field by a factor of 100 or more at all measurement points. This implies that essentially all the power density in the field could be determined by measuring the horizontal magnetic field or, equivalently, the corresponding vertical electric field. The meter readings made in the field were converted to power density and then scaled up to the actual transmitter output power. This scaling factor was determined by the radar crew; because it varied with frequency, a different factor was needed for each of the four measurement frequencies.

Table B-5 shows the measured (and scaled) power density figures and the corresponding calculated values. At positions 1 through 4, distinct beam maxima were found as the beam direction was varied; those maxima are reported on the table. At positions 5 through 8, the maximum was found when the band B beam was steered its full 30° to the right; those values are the ones reported on the table. At position 9, measurements were attempted from all four arrays. However, the levels from bands E and C were very low; those arrays presumably produced a deep null in the direction of position 9. Band D also provided a low level there; the level reported in the table was measured with the beam pointed 30° right. The level from the band B array fluctuated only slightly as the beam direction was varied. At position 10 only band B was measured, and the beam direction was 30° right azimuth.

Although positions 11 through 14 are all directly behind their respective array centers (between the sixth and seventh elements), the maximum power density was not generally found by directing the loop antenna at the array center. Viewed from behind, the elements of bands D and C are tilted 45° clockwise, those of band B are tilted 45° counterclockwise, and only the elements of the band E array are vertical. Thus, in the clockwise-tilted arrays, the dipole elements to the right of the measuring point appear foreshortened so that they are directing less than their full strength at the measuring position; however, because those elements to the left are viewed in essentially their full length, they direct a greater amount of power toward the measurement position. It was confirmed at all four behind-the-array points that the maximum power came from the described direction. Consistent with the fact that the band E elements are not tilted, the maximum power at position 13 was found with the measurement antenna directed at the array center.

Table B-5

COMPARISON OF MEASURED AND CALCULATED POWER DENSITIES
FOR THE ERS TRANSMITTER

Measurement Position[a]	Sector	Relative Azimuth, Z (degrees)	Distance, R (ft)	Band	Frequency (MHz)	Power Density (mW/cm^2) Measured (and Scaled)	Calculated
1	A	0	2,400	C	10.54	0.035	0.22
2	A	0	2,400	E	19.20	0.16	0.34
3	A	0	2,400	D	14.54	0.074	0.18
4	A	0	2,400	B	7.83	0.088	0.14
5	B	35	2,400	B	7.83	0.068	0.15
6	B	42	1,800	B	7.83	0.19	0.35
7	C	50	1,300	B	7.83	0.14	0.15
8	C	65	900	B	7.83	0.39	0.19
9	C	90	500	B	7.83	0.081	0.50
9	C	b	1,200	D	14.54	0.0093	0.025
9	C	b	2,000	C	10.54	7.1×10^{-11}	0.005
9	C	b	1,600	E	19.20	2.4×10^{-11}	0.016
10	C	b	500	B	7.83	0.12	0.26
11	C	b	110	B	7.83	0.049	0.26
12	C	b	115	D	14.54	0.076	0.85
13	C	b	40	E	19.20	0.38	1.5
14	C	b	115	C	10.54	0.069	0.46

[a]See Figure B-11.

[b]These sites have azimuth values greater than 90°.

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Appendix C

ELECTROMAGNETIC INTERFERENCE AND HAZARDS TO SYSTEMS

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Appendix C

ELECTROMAGNETIC INTERFERENCE AND HAZARDS TO SYSTEMS

C.1 Introduction

This appendix presents an analysis of the potential effects on other systems of the operation of an OTH-B radar system transmit site at any of the study areas in southcentral Alaska identified as potentially suitable. The systems considered include those that use the electromagnetic spectrum, as well as others that are not designed to use it but that may be susceptible to the energy radiated by the radar. Systems in the first group include telecommunication and radionavigation systems, all of which are designed to sense electromagnetic energy. Systems in the second group include cardiac pacemakers and electroexplosive devices (EEDs), which may inadvertently be subjected to the radar energy.

Appendix A describes the frequency and time behavior of the radar. Information on the characteristics of the emission is basic to an analysis of the effects of any emitter of electromagnetic fields. An OTH-B radar is a complicated system operating with computer guidance according to preprogrammed operating algorithms and using complex signal processing schemes to extract aircraft tracking information from the backscattered signal. Its beams do not sweep; rather, they probe from one azimuth to another, sometimes in a seemingly random manner. An OTH-B radar has a repertoire of operating bandwidths, and it can switch frequency to illuminate the ocean at different distances and as required by changes in the ionosphere. The operation is not predictable from moment to moment, because the radar's computer may alter the routine barrier scanning operation to provide tracking data on some of the aircraft the radar detects and because the radar operators may decide to abandon a frequency that is experiencing interference. Section C.2 of this appendix discusses the selection of the radar's operating frequency, the radar's emissions, and the propagation of energy by ground wave and sky wave.

Section C.3 analyzes incidental electromagnetic effects of an OTH-B radar. It is divided into two subsections. Section C.3.1 discusses the effects on other telecommunication systems, and Section C.3.2 discusses three inadvertent receivers of energy. In both sections, we first determine whether and how the subject system may be susceptible to the characteristics of the OTH-B signal, and then we attempt to determine the OTH-B signal levels at which the subject system will experience some effect. Having determined those levels, we can estimate the distance from OTH-B at which the effect would occur. Because of the many uncertainties involved in this process, firm predictions are seldom possible.

C.1.1 Background

To determine the likelihood that an emitter of electromagnetic energy will cause electromagnetic interference (EMI) to some other system, some knowledge is required of the operating characteristics of both systems and of the means by which the electromagnetic energy is propagated from one to the other. For example, we must determine the threshold of susceptibility for a system subject to interference--that is, the lowest level of undesired signal that causes some perceptible effect on the susceptible system (or activity). The systems include communication systems and cardiac pacemakers; activities include the handling of volatile fuels and EEDs.

The threshold of susceptibility typically must be determined separately for each pair of interfering system and potentially interfered-with system. This is necessary because the threshold of susceptibility depends not only on the power density of the undesired signal at the potentially susceptible system (and therefore on the distance between them), but also on the frequency of the undesired signal and the characteristics of its modulation. Theory is useful in predicting likely modes of interference and can be of considerable value in predicting thresholds of susceptibility. Measurements, however, are often needed when theory is not sufficient or to confirm the theoretical results. Unfortunately, each new situation is usually unique in some way, and measured susceptibility thresholds applicable to that situation are generally not available.

We can rarely make definitive statements regarding the distances from the radar beyond which a given system will not be affected. Available susceptibility levels are either educated judgments or are based on measurements of only a very few units, generally selected in the hope that they are representative or typical of their type. They could, however, be either more or less susceptible than the entire population of units of that type. The variation in the susceptibility levels of all the units of a type (taken as a group) may be quite large, but is generally unknown. Also, circuit designs change, and the susceptibilities of the systems change with them. The nature of radiowave propagation is such that the level of the interfering signal will not be the same at all locations at the same distance from the source. At a given location, the level varies with time and so dealing with expected, or median, values is common. This is also true of the desired signals, when they are applicable.

In some situations, attempting to determine actual susceptibility is not necessary because standards for maximum permissible fields have been established; in this case, the devices or systems are said to be safe if that field is not exceeded. Such standards exist for EEDs and for fuel handling, and a draft standard was once developed for cardiac pacemakers.

C.1.2 Scope

C.1.2.1 The OTH-B Transmit System

This appendix will deal solely with the emissions of the OTH-B radar transmit system and with their potential to produce EMI in other electronic systems or to imperil systems or devices not intended to receive electromagnetic fields. All information presented here has been obtained from unclassified sources (e.g., Stein, 1982); no classified material was reviewed during the preparation of this appendix.

C.1.2.2 Auxiliary Transmitting Systems

Although several radio transmitting systems will operate as adjuncts to the OTH-B radar system, the scope of this appendix does not include determining their effects on the electromagnetic environment. Any effects would be slight in comparison. The power levels of the adjuncts are to be much lower, and the other systems would generally remain on assigned frequencies.

C.1.2.2.1 Land Mobile Radio Systems

The Air Force will use VHF or UHF land mobile radio systems at both the transmit and receive sites to support maintenance and security activities in the antenna fields and other areas within the complexes. These will be standard, commercially available transceivers such as those used by police, fire departments, the Forest Service, and other organizations. These vehicle-mounted or hand-carried systems will operate on frequencies assigned by the National Telecommunications and Information Administration (NTIA) through the Interdepartment Radio Advisory Committee so as to avoid interference with other users of the land mobile bands.

C.1.2.2.2 Vertical Incidence and Backscatter Sounding

To aid in determining which frequencies to use, and to monitor the ionosphere overhead, both vertical and oblique incidence sounding will be employed. The sounder system will be able to operate over the frequency range of 2 to 30 MHz, but will not transmit on the distress, calling, and guarded frequencies listed in Table A-1, Appendix A. The effective radiated power will be adjustable from 37 to 47 dBW (factors of approximately 40,000 to 4,000 less than the maximum effective radiated power of the radar itself).

C.1.2.2.3 Data Links

Operational data and instructions for controlling the system will need to be transmitted in real time between and among the transmit site, the receive site, and the operations center. A radio system will be used for this purpose. However, the system has not yet been specified, so its effects cannot be described.

C.2 The OTH-B Signal

C.2.1 Frequencies and Their Selection

C.2.1.1 Available Frequency Bands

The NTIA has authorized the OTH-B radar to operate on a "noninterference" basis within any of about 30 bands between 5 and 28 MHz. These bands, within the high frequency (HF) portion of the radio spectrum, are shared with users of the Fixed and the Broadcast Services. The Fixed Service is intended for point-to-point transfer of information between two cooperating fixed (i.e., not mobile) stations. Although various types of modulation, such as voice or teletype, may be used, Villard (1980) indicates that the HF bands are used less frequently for this purpose than before the introduction of satellite systems, which have numerous advantages over HF systems. The Broadcast Service uses transmitters located throughout the world and operated by private industry, governments, religious organizations, and other groups. Those stations operating in the HF band are most often used for international or tropical broadcasting. Hundreds of these stations, including Voice of America, Radio Moscow, and Radio Havana, broadcast news, music, and other features generally intended for listeners beyond the country of origin.

All other portions of the HF band, including the bands occupied by the Aeronautical Mobile and Maritime Mobile Services, by the Amateur Radio Service (i.e., the Hams), and the Standard Frequencies, are forbidden to the radar. The first two services are used for communication between and among ships, aircraft, and shore or ground stations. The Hams are dedicated hobbyists who communicate with other Hams throughout the world using the HF bands. The Standard Frequency bands support transmission of precise time and frequency information, as well as propagation predictions, solar and geophysical data, and the like. They are operated by national government agencies and include WWV in Colorado, CHU in Ontario, and JJY near Tokyo.

Other special purpose frequencies, such as Search and Rescue Control and similar frequencies, are not to be used by the radar. They are listed in Table A-1, Appendix A.

C.2.1.2 Selection of the Operating Frequency

Under normal operation, each of the two antenna arrays or faces of the ARS transmitting system sequentially illuminates its own eight adjacent barrier sectors beyond the horizon. Each of these 16 barrier sectors is 7.5° wide and about 500 miles deep; together they cover a 120° annular barrier region that extends over parts of the Arctic Ocean and the northern Pacific Ocean (see Figure 1-1). The inner edge of the barrier sector varies between 500 and 1,300 miles from the receive site. The operating frequency is independently selected for each 7.5-deg sector according to a number of criteria. Figure C-1 shows the major steps involved in selecting the frequency for one sector; the following paragraphs describe the process.

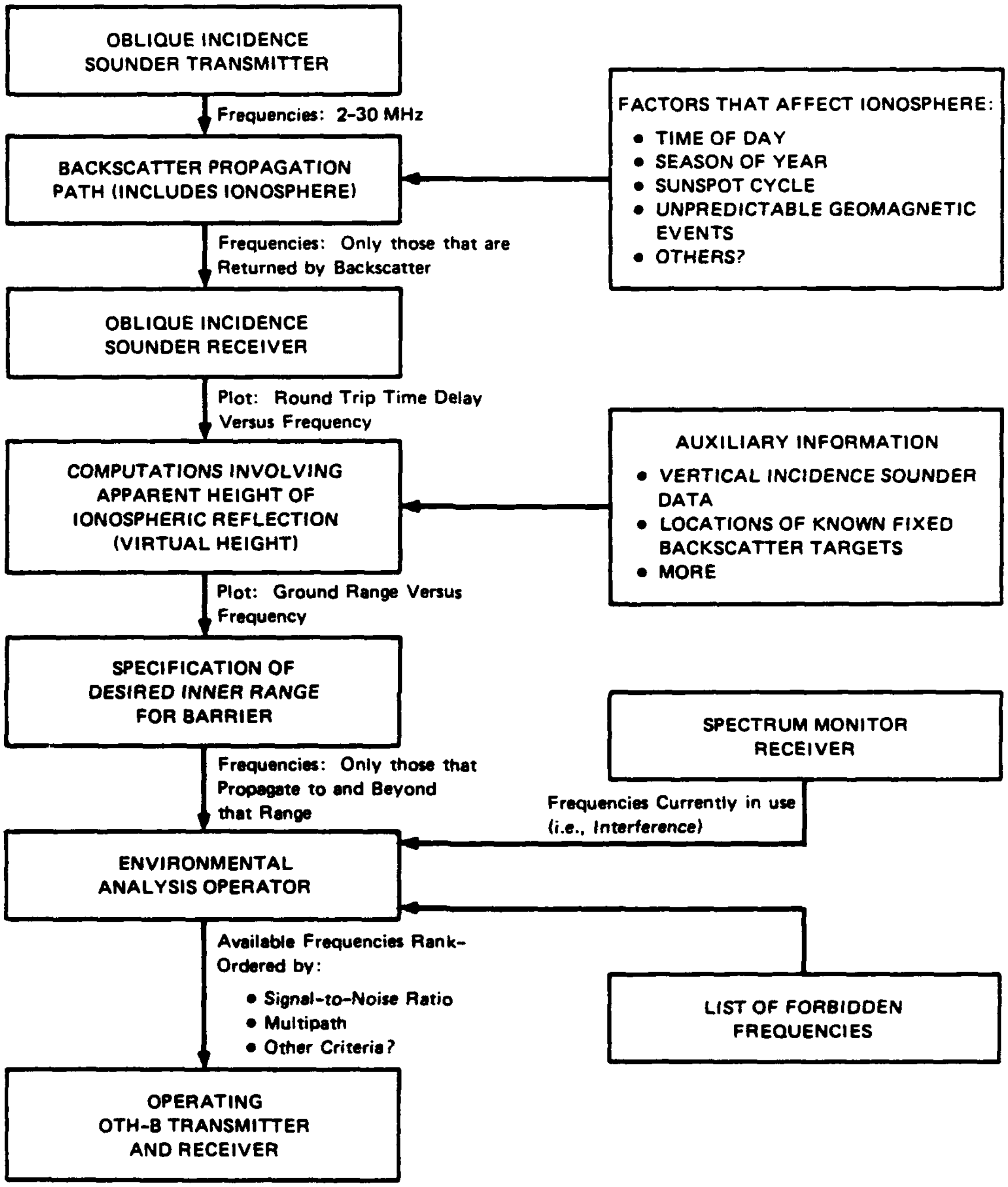


FIGURE C-1 CONCEPTS FOR SELECTION OF OTH-B OPERATING FREQUENCY FOR EACH 7.5-DEGREE SECTOR

A low-power oblique-incidence backscatter sounder transmitter at the OTH-B transmit site transmits signals over the 2- to 30-MHz frequency band toward the barrier sector. The ability of the ionosphere to reflect signals back to the earth at great distances is constantly changing. It depends on the electron density as a function of height, which is controlled by solar illumination and therefore has cyclical variations with time of day, season of the year, and the 11-year solar activity cycle. Noncyclical changes brought about by random solar activity such as solar storms also occur. Thus, only the signals in a fraction of this 28-MHz-wide band will be refracted by the ionosphere to illuminate the earth's surface and from there be reflected back along essentially the same ionospheric path to the backscatter sounder receiver at the OTH-B receive site. The lower end of this band of frequencies may be of little interest, as it may be determined essentially by overhead reflection. The upper end of the returned band of frequencies indicates the highest frequency that the local ionosphere will reflect at that time.

The raw date provided by the oblique sounder system could take the form of a plot showing the signal's round-trip time delay as a function of frequency (for those frequencies that are returned). The OTH-B system then uses auxiliary information, such as the locations of known, fixed backscatter targets, to convert the time delay to the equivalent ground range so that the data could be shown as a plot of ground range as a function of frequency (see Figure C-2).

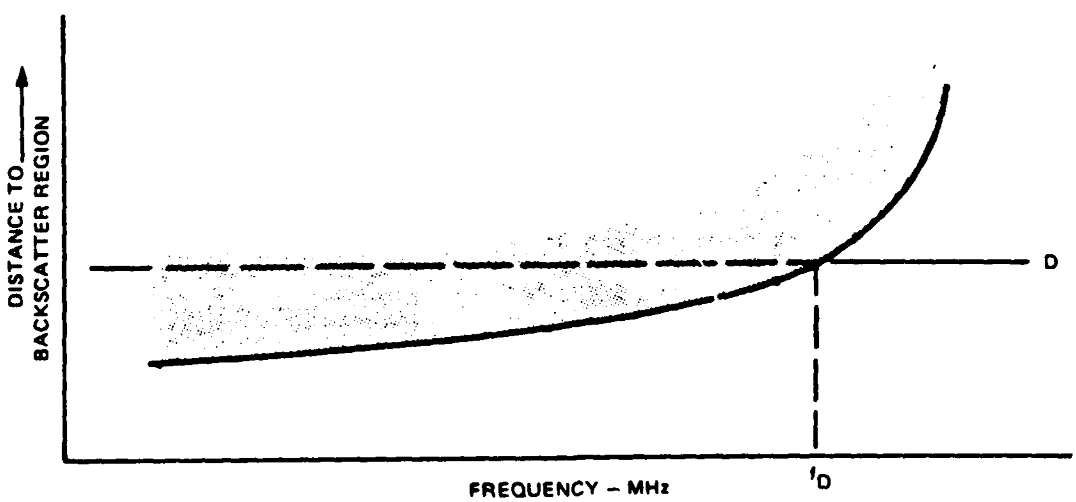


FIGURE C-2 CONCEPTUAL BACKSCATTER IONOGRAM SHOWING THAT FREQUENCIES ABOVE f_D CAN BE USED ONLY FOR DISTANCES BEYOND D

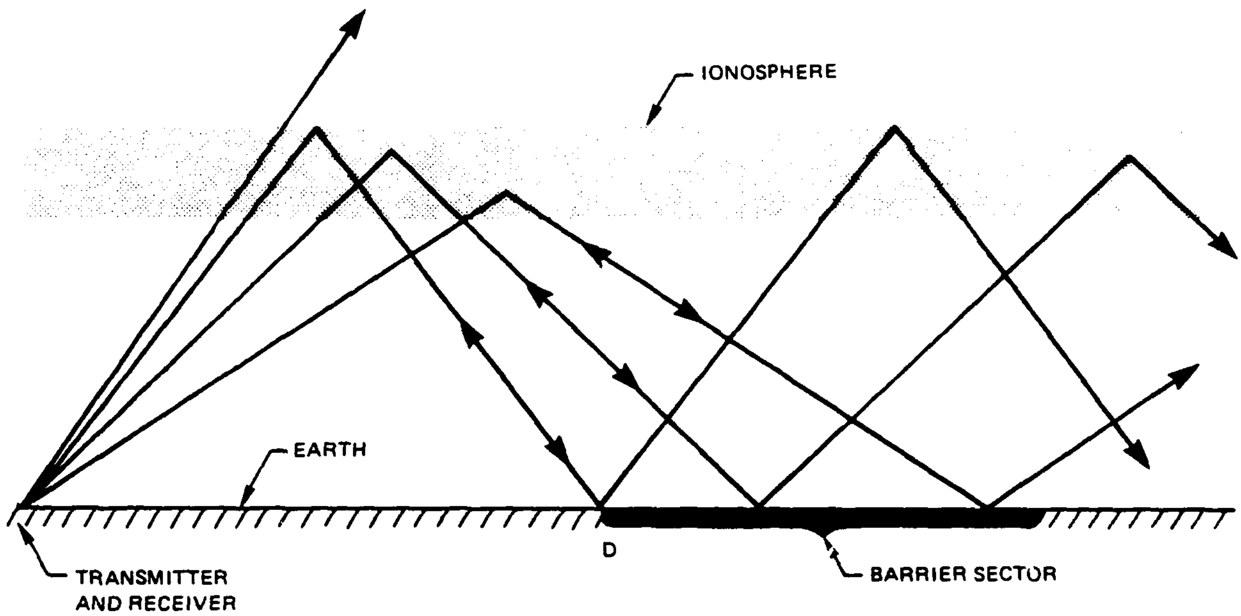
The radar-operator-specified-range to the inner edge of the barrier sector determines the band of frequencies that, strictly from the standpoint of propagation, could be used. Information such as that shown on Figure C-2 would indicate to the radar and its operators that the operator-specified minimum range D can be reached only by using frequencies below the frequency f_D.

Figure C-3 illustrates why this is so. The distance into the ionosphere that a signal at a given frequency will propagate before it is refracted back toward the earth depends on the angle at which it enters the ionosphere; the transmit antenna array, which has a broad pattern in the vertical plane, does not control this angle well. Propagation at the frequency f_D is illustrated in Figure C-3a. At low take-off angles, the signal propagates beyond the distance D into the desired barrier sector; as the take-off angle increases, the wave propagates further into the ionosphere before it is reflected, and the distance to the ground-reflection point eventually decreases to the specified minimum distance D. At take-off angles just steeper than that, the signal passes through the ionosphere and is not reflected back to the ground at all. Points closer than D receive no sky-wave signal at that frequency and are said to be in the "skip zone".

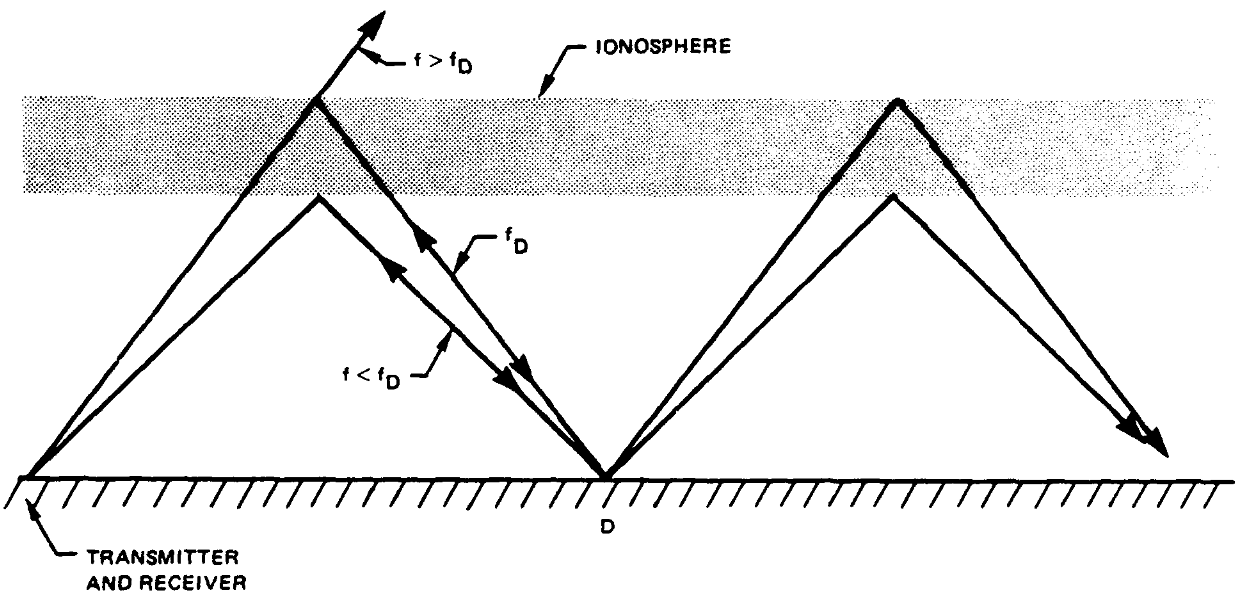
Figure C-3b demonstrates that frequencies less than and up to f_D propagate to the minimum distance D by means of increasingly greater take-off angles. At that maximum take-off angle, frequencies higher than f_D will penetrate the ionosphere; at lower take-off angles, however, these higher frequencies will propagate to minimum distances greater than the distance D.

The band of available frequencies extending up to f_D is then further constrained by the radar's Environmental Analysis Operator, who employs a spectrum monitor receiver to determine, in real time, on which frequencies signals are propagating to the receive site. The radar will generally not be operated on an occupied frequency because that would cause mutual interference. Other, apparently unoccupied, frequencies are used only for emergency traffic and are normally quiet, although they are guarded (i.e., monitored) by various agencies. Thus, the spectrum monitor receiver would generally not find signals on these frequencies. To avoid them, the OTH-B operators maintain a list of these forbidden frequencies; the radar transmitter cannot be operated on any of them. The remaining available frequencies are then ranked in terms of suitability, using criteria such as signal-to-noise ratio and multipath.

The ranked list of "most desirable allowable frequencies" applies only to the particular barrier sector from which the backscatter sounding and spectrum monitoring data were received, and the OTH-B transmitter will use only those frequencies in that sector. Other sectors will have identically derived lists, all of which will be constantly updated as ionospheric conditions change.



(a) PROPAGATION AT THE FREQUENCY F_D
FOR VARIOUS TAKE-OFF ANGLES



(b) PROPAGATION TO THE DISTANCE D BY
FREQUENCIES AT AND BELOW F_D

FIGURE C-3 SIMPLIFIED BACKSCATTER PROPAGATION PATHS

The radar does not generally scan an array's eight adjacent 7.5° sectors in any regular sequence. In fact, to counter any advantage an adversary might gain from a predictable scanning pattern, the radar may illuminate the sectors in an apparently random order. Each 7.5° sector will be revisited within 15 to 60 seconds, for an average dwell time of 2 to 8 seconds. If the radar does produce interference to any other users of the spectrum, these figures would indicate how often this would occur and how long it would last.

C.2.2 Power Transmitted at Various Frequencies

The power emitted by a radio transmitter is never confined completely to the intended bandwidth of operation. A transmitter typically emits some power within the spectrum adjacent to the operating band. It may also emit some power on frequencies that are integer multiples of the operating, or fundamental, frequency; these frequencies are called harmonics. Further, noise and spurious signals may be generated within portions of the transmitter system that are amplified and then radiated by the antenna system.

C.2.2.1 The Transmitted Spectrum in and near the Operating Band

The most common waveform of the OTH-B radar will be a linear frequency modulated/continuous wave (FM/CW) waveform such as is illustrated in Figure A-1, Appendix A. The three parameters--center frequency (f_o), period (T), and operating bandwidth (B)--are varied according to the needs of the radar system. The center frequency is selectable in 1-Hz increments within the 5- to 28-MHz band, and the signal sweeps within a selected operating bandwidth about that center frequency at some waveform repetition frequency (WRF), which is the inverse of T, shown in Figure A-1.

The modulation has been designed to minimize the transmitted power that falls outside the operating bandwidth so as to decrease the likelihood of interference to users of the adjacent radio spectrum. Figure C-4 shows the maximum allowable power spectral density (in a 1-Hz band) as a function of frequency offset (Δf) from the center frequency (Snyder, 1982). These simplified curves are upper bounds for the actual transmitted spectrum, which has a very complicated appearance. They show, for example, that for a radar operating bandwidth of 10 kHz and a WRF of 60 Hz, the power density at a frequency 20 kHz above or below the OTH-B center frequency will be at least 47 dB lower than the power density in the operating bandwidth. That is, if the radar is operating at its full 1.2-MW output power, the output power apparent to a receiver 20 kHz from the radar's center frequency is 47 dB lower (a factor of more than 50,000) than 1.2 MW, or only about 24 W. If the WRF is reduced to 20 Hz, the power density for the same Δf is about 6 dB (a factor of about 4) lower than at a WRF of 60 Hz.

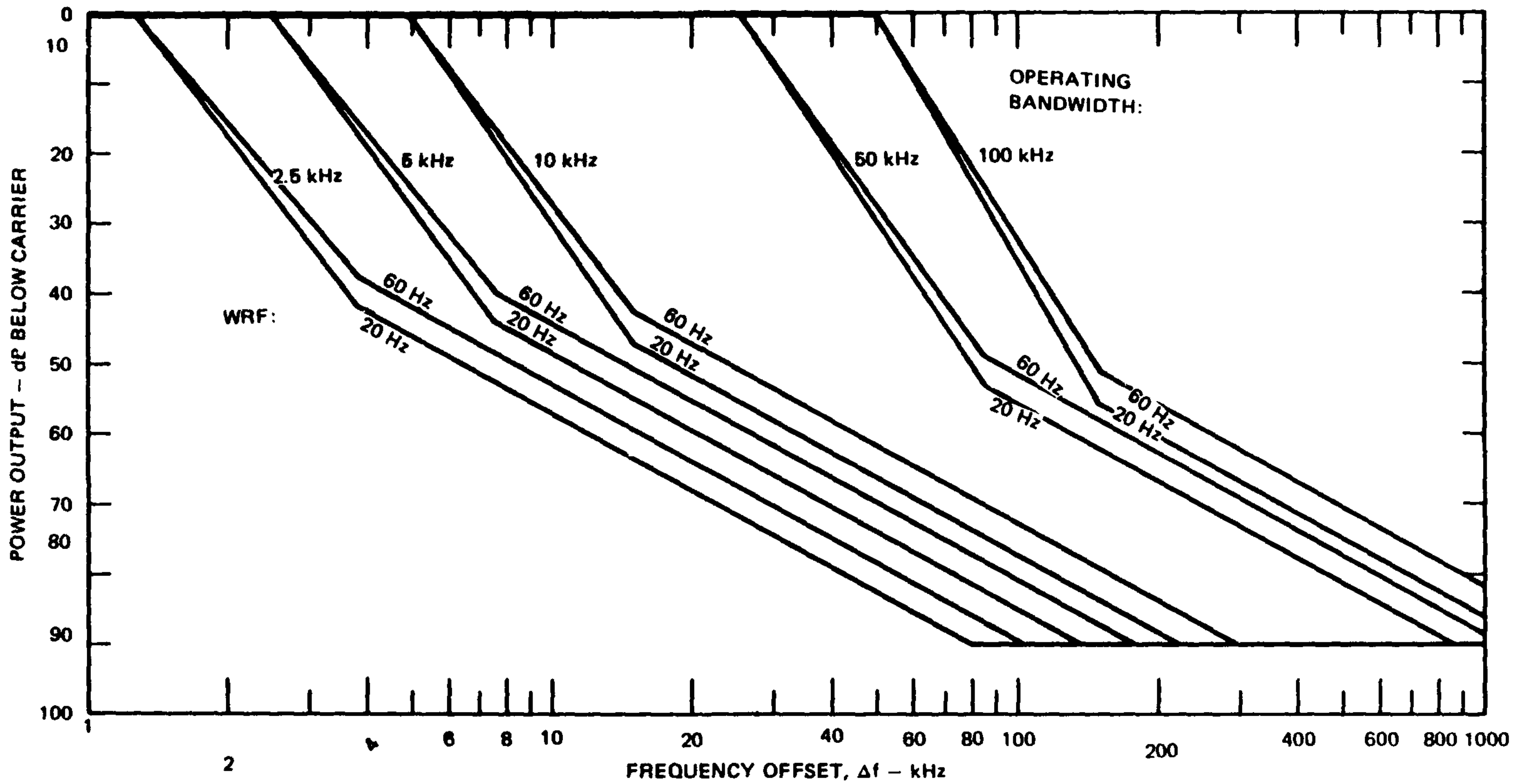


FIGURE C-4 THE ENVELOPE OF THE TRANSMITTED SPECTRUM—POWER DENSITY AS A FUNCTION OF OFFSET FROM THE CENTER FREQUENCY

C.2.2.2 Harmonics

The OTH-B system specification indicates that the harmonics from each transmit array shall be at least 70 dB weaker than the fundamental signal. This does not imply that radiated harmonics will be only 70 dB down from the radiated fundamental; they will be considerably weaker than that because the antenna system will not provide high gain at the harmonic frequencies. Recall that the transmit antenna system is a phased array. Each array has 12 transmitters, each supplying power to one dipole element of the band in use at the time. The system forms its high-gain, relatively narrow beam by carefully timing the transmitter output signals so that precise phase relationships exist between the signals emitted by each of the 12 dipole elements. This careful timing must account for the electrical length of the coaxial transmission line between the transmitter and the antenna, which is different for each of the 12 transmitter/dipole pairs. Further, the antenna elements are placed so that certain phase relationships exist between the signal directly radiated by each dipole element and those reflected from the groundscreen, the backscreen, and the adjacent dipoles. The appropriate phase relationships will not exist at harmonic frequencies, so that the harmonic signals radiated by the antenna system elements (and reflected from the groundscreen and backscreen) will be randomly phased. Therefore, the array will not form a high-gain beam at the harmonic frequencies as it does at the fundamental.

Table C-1 lists the frequency bands into which harmonics may fall, in order of decreasing amplitude at the output of the transmitter (Lyon, 1982); because of the phase scrambling described above, this particular order may not hold for the radiated harmonic signal. The gain of the antenna system is about 22 dBi at the fundamental frequency. Because the antenna system will not have a high gain at the harmonic frequencies, however, the radiated harmonic signals will be much more than 70 dB below the fundamental. Estimates of 80 to 90 dB are not unreasonable.

Table C-1

HARMONIC FREQUENCY BANDS OF THE OTH-B RADAR

Harmonic	Frequency Band (MHz)
Fundamental	5 to 28
2nd	10 to 56
4th	20 to 112
6th	30 to 168
3rd	15 to 84
8th	40 to 224
5th	25 to 140

Thus, because the effective isotropic radiated power (EIRP) of the radar at fundamental frequencies is about 82.8 dBW (the radar's output power of 1.2 MW, or 60.8 dBW, and its antenna gain of 160, or 22 dBi, yields an EIRP of 82.8), the EIRP at the harmonics will be on the order of 0 dBW (1 W) or much less.

C.2.2.3 Noise and Spurious Outputs

Transmitter noise and spurious output signals from the transmitters are to be at least 90 dB below the fundamental, when measured in a nominal 1-Hz bandwidth more than 2 Hz away from the fundamental. An exception is that harmonics of the 60-Hz power line frequency are required to be only at least 70 dB below the fundamental.

C.2.2.4 Power Reduction

The OTH-B radar will not need to be constantly operated at its full 1.2-MW power; when an adequate signal-to-noise ratio can be achieved with a lower output power, the radar's power level will be decreased independently for each 7.5° sector in steps of about 1 dB (Villard, 1980). The maximum available power reduction is about 15 dB, a factor of about 32; thus, the radar might sometimes operate using as little as 37 kW.

C.2.3 Signals Propagated by Sky Wave

Each of the 16 independent barrier sectors will be periodically illuminated by an ionospherically reflected sky-wave signal at a frequency selected as optimal for that sector at that time. The radar is highly adaptive. Because ionospheric propagation conditions are constantly changing and because the radar avoids frequencies that are obviously in use, predicting its detailed frequency use is impossible. The frequencies used will most likely be higher during the day than at night and in summer than in winter. Large frequency changes on any given sector will probably be required shortly after the sun strikes the ionosphere near the reflection region.

Regions other than the desired barrier sectors will also be illuminated by sky-wave signals. As Figure C-3 indicates, the signal may take another hop or more beyond the barrier sector, depending on the condition of the ionosphere at subsequent potential reflection regions. Further, the radar's backlobes, which are weaker than the main beam by at least 20 dB (a factor of 100), may propagate by sky wave to regions behind the radar that are approximately the same distance away as are the barrier sectors.

In addition to the fundamental and frequencies adjacent to the fundamental, some harmonics and spurious signals could propagate by sky wave. Only those below about 30 MHz could ever be expected to do so, and they would not necessarily propagate to the same regions as does the fundamental. Harmonics above about 30 MHz would not be reflected back

to the earth by the ionosphere and so would not propagate to distant regions.

C.2.4 Signals Propagated by Ground Wave

Some of the energy radiated by the antenna system remains near the earth's surface, where it propagates by ground wave, becoming attenuated as a function of distance much more rapidly than does the sky wave. (Ground waves account for the daytime coverage of the AM broadcast stations.) Figures C-5 and C-6 show estimates of the field strength at 6 MHz and 25 MHz, respectively. These two frequencies are at the approximate centers of the lowest and the highest of the radar's six frequency bands. The field strengths were estimated using a computer formulation of the empirical propagation model of Norton (1941) for vertical polarization and low antenna heights, as discussed by Terman (1943) and by Duff and White (1972).

Two curves, labeled "thawed" and "frozen," are shown for each frequency. Both apply roughly to permafrost regions to the west (i.e., in front) of the transmit site. Behind the radar, the signals will be about 20 dB (one hundred times) lower.

The ground constants used here are taken from a report by Sailors, Moision, and Roy (1983). If actual measurements of the ground constants at the transmit study areas are made, calculations based on the measurements would provide improved estimates of ground-wave propagation.

For two reasons, these curves probably show field strengths considerably greater than would normally occur. First, the curves show field-strength estimates for the radar's maximum allowable EIRP, which would not be used at all times. At 25 MHz (band F), the antennas are vertically polarized and the curves are based on the full 82.8 dBW for the EIRP. At 6 MHz (band A), the antennas are rotated 45° so that one-half the power radiated is horizontally polarized; a horizontally polarized ground wave is attenuated so rapidly with distance that it can be ignored relative to the vertically polarized ground wave. Thus, we can consider the maximum available ground-wave EIRP for band A to be one-half the actual maximum, or 79.8 dBW.

The second reason that the curves are probably pessimistically high is that the model applies for a "smooth spherical earth" with "uniform ground constants surrounded by an atmosphere in which the dielectric constant decreases uniformly with height," so that "the departures from these idealized conditions, such as hills, buildings, trees, etc., cause large variations from the calculated values" (Norton, 1941). Thus, Alaskan mountains will probably reduce the actual field strengths to below these predictions, particularly at distances of tens of miles or more.

The limiting distance at which the OTH-B ground-wave signal could be received, provided that the receiver in question was tuned to a

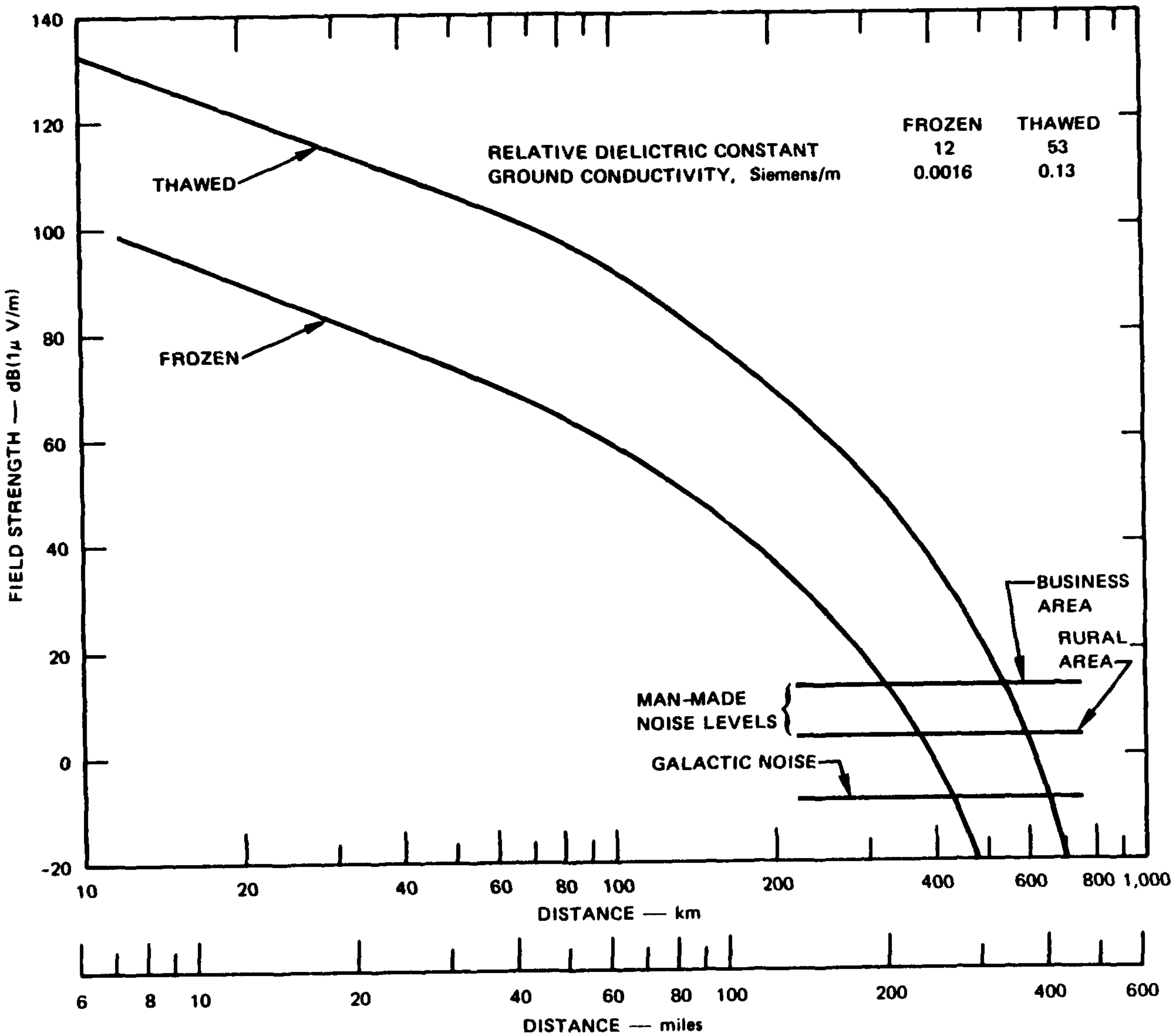


FIGURE C-5 VERTICALLY POLARIZED GROUND-WAVE FIELD STRENGTH OVER PERMAFROST IN FRONT OF ANTENNA—6 MHz

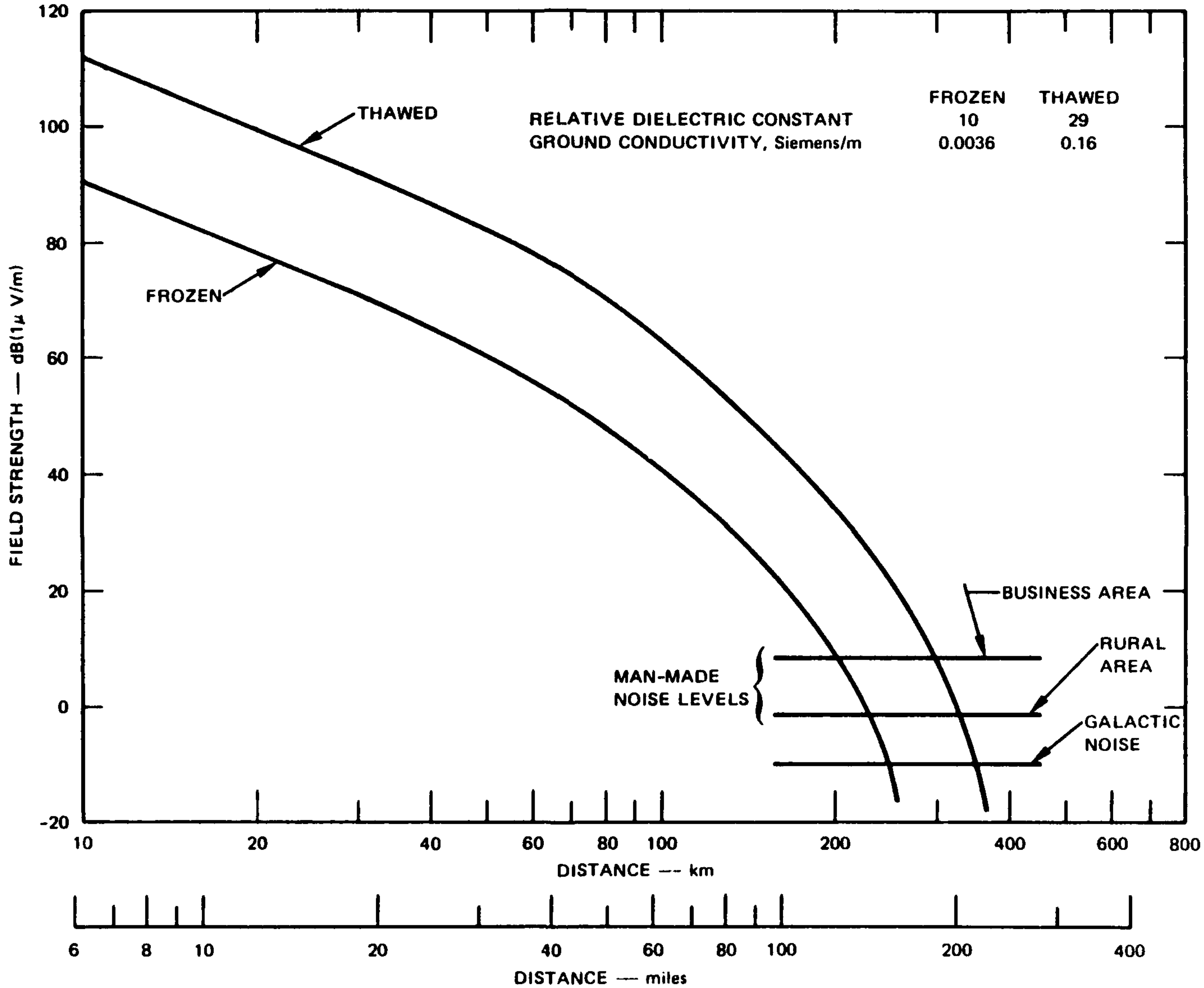


FIGURE C-6 VERTICALLY POLARIZED GROUND-WAVE FIELD STRENGTH OVER PERMAFROST IN FRONT OF ANTENNA—25 MHz

frequency in use or about to be used by OTH-B and that no other signals were in that frequency band, would be determined by the radio noise level in that same band at the receive site. If the power of the radio noise exceeds that of the OTH-B signal, the OTH-B signal will not be noticeable.

If the receiver were already tuned to some desired signal, the maximum distance at which the OTH-B ground wave could produce interference would be even less. To be noticeable, the OTH-B signal would have to exceed the combined power of the noise and the desired signal (which itself would have to exceed the noise to be useful).

The predominant noise in the HF band is seldom the internally generated noise of the receiver system. Instead, the predominant noise is usually that originating from natural or man-made sources and entering the receiving system through the antenna array. The most important source of naturally occurring noise at frequencies up to about 20 MHz is the thunderstorm; radio noise from lightning propagates by way of sky wave, so that major storm centers influence the noise on a global basis. Because the general times and locations of major thunderstorm activity and the nature of the seasonal and diurnal variations in sky-wave propagation are known, this atmospheric radio noise can be statistically predicted. Such predictions are available as a function of frequency, location, season, and time of day in a report most commonly referred to as CCIR 322 (C.C.I.R., 1964). Recently, the CCIR-322 atmospheric noise estimates have been improved (Spaulding and Washburn, 1985), and these improved estimates were used here. Above about 20 MHz, atmospheric noise, which decreases quite rapidly with increasing frequency, is likely to be exceeded by galactic radio noise, which originates from the stars and does not propagate from other areas of the earth by sky wave. In Alaska, the atmospheric noise is so low that this generally holds true at frequencies down to 6MHz; only occasionally does the atmospheric noise rise above the galactic noise.

Man-made radio noise is the predominant noise at some frequencies in some areas--particularly in regions of high population density or heavy vehicle traffic. The major sources of man-made radio noise are high-voltage power transmission and distribution lines, automobile ignition systems, electrical motors, and fluorescent lights. Predictions of man-made noise are provided as a function of frequency for business areas, residential areas, and rural areas (C.C.I.R., 1976).

The noise predictions, which are expressed in terms of noise power available in a certain bandwidth at the terminals of an electrically short vertical antenna, can be converted to some other bandwidth and then to the equivalent field strength for comparison with the predictions of the ground-wave field strength produced by an OTH-B radar (Crippen, 1970). Although the median predicted atmospheric noise field strength for Alaska, in a 6-kHz bandwidth at 6 MHz, has clearly defined diurnal and seasonal variations, it is usually masked by the galactic noise. Although no such diurnal predictions are available for the man-made

noise, it too can be expected to vary, being controlled by factors such as times of high traffic density, working times, and, for power line noise, local weather conditions. In business, residential, or even rural areas of Alaska, the man-made noise at HF will probably always predominate over the atmospheric noise, and thus man-made noise usually constitutes the limiting factor in reception of signals. In extremely remote areas, the man-made noise would be so low that the galactic noise would predominate.

The noise information has been transferred to Figures C-5 and C-6 to indicate the distances at which the OTH-B ground-wave signal would be likely to drop below the prevailing radio noise. Note that a 6-MHz signal would propagate farther than a 25-MHz signal; frequencies between these two would propagate to intermediate distances. These pessimistic predictions show the ground wave as stronger than it would probably be; the figures show the OTH-B field strengths that would result from full authorized power and smooth-earth propagation. The radar, however, is surrounded by mountain ranges, through which the ground wave will be severely attenuated. Thus, we do not expect that the OTH-B ground wave will ever be detectable at distances as great as those suggested by these curves. Measured ground conductivity data will permit better predictions.

C.2.5 The Experimental Radar System

A version of the OTH-B system termed the Experimental Radar System (ERS) was built and operated in Maine to test and evaluate many of the radar's operational concepts and to determine the interference that might occur. The ERS had only one of the two independent arrays that the ARS would have. Antenna arrays were not constructed for bands A and F; only frequencies between 6.74 MHz and 22.25 MHz were available.

The ERS was operated for about 1 year ending in January 1981. Although it did not generally operate 24-hr/d, the radar was usually operated during the ionosphere's day-to-night and night-to-day transition periods, when frequency changes would most likely be needed. The ERS logged a total of about 900 hours of transmit time, with output power typically at about 720 kW. Some full-power tests were also run (Raffa, 1982).

C.3 OTH-B Effects on Systems

C.3.1 Telecommunication and Airnavigation Systems

C.3.1.1 Effects within the Radar's Authorized Operating Bands

The radar is authorized to operate within any of about 20 blocks of the radio spectrum between 5 MHz and 28 MHz that are also occupied by stations of the Fixed Service or the Broadcasting Service. Operation of the radar is intended to produce minimal interference with other users of these same portions of the spectrum, and operation of the ERS in Maine indicates that this can be achieved. Occupied channels are avoided both

to prevent interference to others and to prevent others from interfering with the radar's operation. Over the more than 1 year that the ERS was operated, the Air Force determined that it generally had to change its operating frequency several times during an 8-hour shift to avoid interfering signals, but that clear 10-kHz channels for routine surveillance were always available, except for a brief time in the winter, when only 5-kHz channels could be found.

Of the two services, the Broadcasting Service is less likely to share the bands with the radar. Air Force operating procedure will be to attempt to "find an unused frequency in the fixed (point-to-point) section of the HF spectrum" (Thomas, 1980), and the "policy is to conscientiously avoid the use of the SWBC (short wave broadcast bands) wherever possible" (Bayer, 1981). Both Fixed and Broadcast Services generally can change their frequency, either to respond to changing ionospheric conditions or to serve different parts of the world. Broadcast stations often use several transmitters to transmit simultaneously on more than one frequency.

To avoid producing interference to the greatest number of other receivers, use of the Fixed bands is a reasonable policy and will be adhered to whenever possible. In the Fixed Service, transmissions are intended to be point-to-point; only two stations are involved, and only the receiver is potentially susceptible to interference from the radar. No others are authorized to receive these transmissions. On the other hand, "broadcast" implies the existence of numerous intended receivers, any of which might be susceptible. When operating in the Fixed band, the radar will stay far enough away from the band edges to minimize the possibility of interference to other users, such as broadcast receivers.

Although intermittent operation of the ERS for more than a year produced several complaints of interference, only one actually corresponded in time and frequency with an ERS transmission. All reported complaints are listed in Table C-2, which shows that the ERS was generally not operating when the interference was claimed. The single possibly valid complaint was logged by a Military Affiliate Radio System (MARS) station in Florida, which is a Fixed station that uses 20.9375 MHz on a "limited schedule basis" (Abel, 1981) to pass message traffic to military families stationed in Germany. The radar was already operating on the frequency at the time the MARS station was expecting to use it, making it impossible for the MARS station to do so. This one-time problem was resolved within the military.

The ARS will differ from the ERS in that it will have two independently operating transmit arrays instead of one; it will be able to transmit on band A (5.0-6.74 MHz) and band F (22.25-28.00 MHz), which were not available to the ERS; its maximum available transmitter power will be slightly greater; and it will operate continuously. Like the ERS, the ARS will have the clean spectrum illustrated in Figure C-4, which limits the likelihood of adjacent-channel interference.

Table C-2

REPORTS OF ERS INTERFERENCE

Date and Time (1980)	Location	Frequency (MHz)	Service	Source of Information[a]	Assessment
15 Feb through 4 March (8 hours)	Jonesport, ME	54-60 76-82	TV channels 2 and 5	A	ERS transmitted for only 4 min during reported interference periods.
22 April	Canal Zone	18.019	Aeronautical Mobile	A	ERS transmitting on 10.540 MHz.
23 April	Canal Zone	18.019	Aeronautical Mobile	A	ERS not transmitting during reported interference period.
29 April, 2019Z	Not stated	10.54	Fixed	R	ERS not operating at the time.
8 July	Sweden	15.255	Broadcast	A	ERS transmitting on 11.605 MHz
8 July, 1923Z	Not stated	15.245	Broadcast	R	ERS not operating at the time.
Not stated	Not stated	3.975	Amateur, Fixed, & Broadcasting[b]	R	Not within the ERS frequency range.
16 Sept.	Philadelphia, PA	21.780-21.795	Fixed	A	ERS transmitted successively on 20.944, 20,815, and 20.096 MHz during the reported interference period.
16 Sept., 1430Z	Not stated	20.944	Fixed	R	ERS not operating at the time.
16 Sept., 1446Z	Not stated	20.815	Fixed	R	ERS not operating at the time.
16 Sept., 1557Z	Not stated	17.775	Broadcast	R	ERS not operating at the time.
16 Sept., 1846Z	Not stated	20.096	Fixed	R	ERS not operating at the time.
16 Sept., 20??Z	Not stated	21.780	Fixed	R	ERS not operating at the time.
17 Sept., 2036Z	Not stated	21.770	Fixed	R	ERS not on this frequency.
30 Jan. 1981	Florida	20.9375	Fixed (MARS)	A	ERS was transmitting on this frequency, which the MARS station uses on a limited schedule basis.

[a]Sources: "A" refers to Abel (1981); "R" refers to private communication from Raffa (1982).

[b]Services that might be on 3.975 MHz vary from one part of the world to another.

The probability of interference to HF reception by the radar's ground-wave signal is slight. As has been pointed out, the ground wave will quickly be attenuated by distance to levels below the ambient noise. It will be undetectable at distances beyond about a very few hundred miles--or possibly much less; major mountain ranges in front of the arrays, which will greatly attenuate radio signals, are not accounted for in the ground-wave field strength predictions. Thus, only HF listeners within a limited range could possibly detect the ground-wave signal. Because the study areas are far removed from any major population center, the number of such listeners is small. If an HF listener were within the range of the ground-wave signal and receiving a sky-wave signal from some distant transmitting station, however, that signal would also most likely be received by the radar, and the frequency would therefore be rejected as an operating frequency.

The probability of interference by the radar's sky-wave signal is higher, and such interference could occur virtually any place at locations one or more ionospheric hops distant from the transmit site. Interference could occur if a distant transmitter were propagating a signal to various parts of the world that, because of ionospheric propagation conditions, did not include the radar site. (As one simple example, if an HF transmitter were about 100 miles away, neither its ground wave nor its sky wave would reach the radar.) In that situation, although the radar system monitors the spectrum before transmitting, the radar operators would believe that the in-use channel was clear and would feel free to use it. They could not realize that the radar signal could be producing interference at some far distant location, depending on the relative levels there of the radar signal and the desired signal. Because the radar signal involved could be emitted by the main lobe, backlobes, or sidelobes, and because the signal could propagate by more than one hop, predicting when or where this may occur is impossible.

This interference would not necessarily be constant. Each of the radar's two arrays switches its beam to sequentially illuminate its eight 7.5°-barrier sectors, and it would use the same or different frequencies for each. If the same frequency were in use, the interference might occur only for the roughly one-eighth of the time the radar's beam is directed appropriately. If different frequencies were used for each barrier sector, the interference would occur only for the approximately one-eighth of the time the radar was using the one particular interfering frequency. The Air Force does not wish to release precise information on how long the radar would typically keep its beam on a given barrier sector or how often it would probably revisit it, and so we can make no definitive statements regarding the duration of such an interference episode or the interval between them. Some evidence shows that the duration might be as short as 10 seconds, however, which would imply that the interference would occur in 10-second episodes every 80 seconds.

C.3.1.2 Effects Outside the Radar's Authorized Operating Bands

C.3.1.2.1 Effects on Amateur Radio

The Amateur Radio Service occupies several bands within or adjacent to the range of frequencies used by the radar (see Table C-3). Except for the 40-m band, all are set aside worldwide for the exclusive use of the amateurs. (The 40-m band is used by amateurs only in North and South America; in the rest of the world, it is allocated to broadcasting.) Because these bands are among those that can be supported by ionospheric propagation, the amateurs use them for contact with other amateurs throughout the world. Although contact is casual, the amateurs have often provided urgently needed emergency communication services following disasters such as tropical storms, tornados, or earthquakes.

Table C-3

AMATEUR RADIO BANDS NEAR THE OTH-B FREQUENCIES

Common Terminology	Frequency Band (MHz)
40-m band	7.0 - 7.3
20-m band	14.0 - 14.35
15-m band	21.0 - 21.45
10-m band	28.0 - 29.7

Although the Air Force does not intend to operate the OTH-B radar in the amateur bands, all bands listed in Table C-3 are adjacent to bands in which the radar can be expected to operate. Thus, enough of the radar's energy could possibly fall into an amateur band to produce interference to the users there (see Section C.2.2.1). Because the energy could be emitted by the radar's sidelobes or backlobes, as well as the main beam, and because it could propagate by sky wave, specifically predicting when or where any interference would occur is impossible.

A 5-page article describing the ERS and the interference effects that might occur was published in a leading amateur radio magazine in 1980, about the time the Air Force began testing the ERS (Villard, 1980). The amateurs were informed that the radar, if heard on an AM receiver, would sound like a hum "at any one of several modulation frequencies from 20 Hz to 60 Hz," which are, of course, the WRFs. The article not only urged the amateurs to submit reports of any interference to the OTH-B Program Office at Hanscom AFB, but it also stated that the "Air Force will welcome amateur reports of its signals and their apparent level, whether there is interference or not" (Villard, 1980).

No reports of ERS-produced interference in the amateur bands were ever received at the OTH-B Program Office (Raffa, 1982; Abel, 1981), indicating that this type of radar can operate without unduly affecting users of the adjacent channels.

C.3.1.2.2 Interference to Television

C.3.1.2.2.1 The Television Environment in General

In the United States, television is broadcast in two frequency bands: The VHF TV channels (those from channel 2 through 13) occupy portions of the spectrum between 54 MHz and 216 MHz; the UHF channels (those from channel 14 through 69) occupy the continuous spectrum between 470 MHz and 806 MHz. The OTH-B radar will occupy portions of the spectrum between 5 MHz and 28 MHz, well below the frequencies used for TV broadcast.

When applying for a license to operate, a TV station's engineers calculate and provide contours of predicted TV signal strength that define the station's intended coverage area. These are statistical predictions because they cannot take into account all the many variables of terrain, location, and equipment that affect the reception. At the Grade A contour, by definition, the median field strength at a standard 30-ft antenna height must be sufficient to provide service (at the best 70% of the receiving locations) that the median observer would consider "acceptable" at least 90% of the time, using an antenna equivalent to a half-wave dipole (i.e., a rabbit-ear antenna). At the more distant Grade B contour, the median field strength at the standard antenna height must be that which provides the observer with "acceptable" TV reception at only the best 50% of the receiving locations and only if an antenna with a gain 6 dB higher than that of a dipole is used. (Such an antenna would probably be a multielement Yagi.) The locations of the Grade A and Grade B contours are determined using FCC-approved methods to predict the signal strengths.

In some (generally mountainous) areas, TV coverage is available only from low-power translators, generally installed on a high hill or mountain-peak, where direct reception from a distant TV transmitter is possible. After the translator receives the direct broadcast TV signal (usually using a high-gain directional antenna), it amplifies and rebroadcasts the signal on another channel at relatively low power to provide service within a small area.

C.3.1.2.2.2 The TV Environment in Alaska

An in-depth study of the TV environment near the ARS transmit study areas has not yet been made. Where there is TV reception at all, it is probably either by means of broadcast-translators, private earth stations, or the state's Entertainment Television Project.

Because of Alaska's rough terrain, and the concentration of most of the population in the three cities of Anchorage, Fairbanks, and Juneau, broadcast TV does not cover most of the physical extent of the state. The regions around the ARS study areas are all far outside the service areas of the TV broadcast stations of Anchorage and Fairbanks (Television and Cable Factbook, 1983).

A TV translator is sometimes placed on a favorably located hilltop above a community that cannot receive the same direct-broadcast TV signal that reaches the better-located translator. The translator changes the signal to another channel and rebroadcasts it at low power for local reception. Presence of translators near the study areas is not yet known.

A few people in the Lower 48 receive television directly from geostationary satellite transmission in the 3.7- to 4.2-GHz band using privately owned earth stations. Such systems are becoming more popular because they can provide high-quality television reception in remote areas, and their price has dropped in the last few years to the $2,000 to $5,000 range. Whether any of these exist near the study areas has not yet been determined.

Alaska has an unusual satellite system to provide both educational and entertainment TV to towns and villages that are not served by the broadcast stations in the cities (Hills, 1983). TV programming is transmitted by satellite from originating points in the Lower 48 states to television stations in Anchorage, Fairbanks, Juneau, and Sitka, where it is taped. The taped TV programming is later retransmitted by satellite to more than 200 small towns or villages, each of which has a small earth station used for TV as well as for the telephone system. At the local earth station, the TV programming is frequency-shifted to standard VHF or UHF TV channels and is rebroadcast for local use using low-power transmitters, such as are commonly used for mountain-top translators.

The populations of Glennallen, Gulkana, and Tok are large enough that they are probably served by the Entertainment Television Project. Considering the broad extent of this system in Alaska, project stations may also exist near the more remote Paxon East and Indian Creek study areas.

C.3.1.2.2.3 Common Interference Mechanisms

Interference from the radar's harmonic or spurious emissions could occur if the emission falls in a TV channel being viewed, and if it is of sufficient strength relative to the TV signal to noticeably degrade video or audio quality. The TV picture is normally much more susceptible to interference than the audio portion. According to information provided to Abel (1980a), the lowest ratio of picture-carrier power to interference power at which a trained observer can notice interference is 46 dB.

Fundamental overload and high-power interference effects could occur to a TV receiver only within a very few miles of the transmit site. Fundamental overload could occur (usually only at VHF TV channels) if the fundamental signal from the transmit site were strong enough at the TV set's antenna terminals to overload the TV tuner's input circuitry. Modern TV receivers, however, are typically equipped with a simple high-pass filter in the tuner's antenna input to provide a moderate degree of overload protection from signals at frequencies below the TV broadcast band. For extreme cases, for which the internal filter is inadequate, an external filter could be installed in the antenna lead to provide additional protection.

Antenna-mounted preamplifiers, sometimes used for improved reception in low-signal-level areas, are often quite susceptible to fundamental overload. When this type of interference occurs, the remedy is to install a high-pass filter between the antenna and the preamplifier. Several manufacturers make such high-pass filters for installation inside the preamplifier case.

High-power interference effects occur when a receiver is so close to the transmitter that the RF energy coupled either directly into the receiver circuits, or through the power line is sufficient to produce interference.

No interference to direct satellite TV receiving systems or to the village satellite TV receiving systems should occur, because of the great separation between the satellite frequencies and those of the OTH-B radar.

C.3.1.2.2.4 TV Interference Experience at the ERS

Measurements in Maine in the vicinity of the ERS indicated that at distances of 6 miles or more from the radar, the radar's harmonics that could potentially interfere with television were much weaker than predicted and were generally so weak that they were not detectable above the background radio noise (Abel, 1980a). This indicates that they could not produce interference at such distances; no complaints of TV interference were ever logged.

Similar results could be expected in the vicinity of the ARS.

C.3.1.2.2.5 Assessment of the Likelihood of Interference to Television

High-power effects are not likely to be widespread because of the large distances between the study areas and concentrations of TV viewing households.

Fundamental overload interference would also be unlikely. Any such cases could be inexpensively remedied by installing high-pass filters in the TV receiving system.

The interference resulting from the radar's harmonic or spurious emissions, however, could interfere with the reception of TV translators' signals. Further, if the translator is receiving a direct-broadcast TV signal (not a satellite signal), they could interfere with reception at the translator, thereby contaminating the signal being retransmitted. This latter interference would have the most impact, because it would degrade TV reception for all viewers served by the translator.

Because harmonic interference depends on the appropriate frequency relationships between the TV frequency and the frequency in use by the radar, the interference would be intermittent if it ever were to occur. The radar would have to be transmitting on the appropriate subharmonic of the TV signal. As an example, the picture carrier of a channel-5 signal is at about 77.25 MHz. For third-harmonic interference, the radar would have to be using a frequency very close to 25.75 MHz.

Even given that the frequency relationships might sometimes be appropriate to produce interference, the actual occurrence of interference from the harmonics or spurious signals depends on a number of imperfectly predictable factors. Among them are: (1) the level of the radar's emissions in the TV channel; (2) the field strength of the TV signal at the receiver location; (3) the directional characteristics and the orientation of the TV receiving antenna relative to the transmit site; and (4) the distance and terrain characteristics between the transmit site and the TV receiving location.

Predicting interference for each TV receiver in any general area is not feasible, and site-specific information is inadequate to predict the "typical" situation. Because of the great uncertainties and range of variability of the factors listed above, however, when the results of interference prediction calculations for so-called typical cases are eventually compared with actual experience, the actual results can be significantly different.

C.3.1.2.3 Effects on Land Mobile Radio

The MITRE Corporation made measurements to indicate whether ERS harmonics would be likely to produce an interference threat to low-band VHF (roughly 30 to 50 MHz) mobile radio (Abel, 1981). As the ERS was operating, measurements were made on 10 frequencies between about 32 MHz and 57 MHz that were second, third, fourth, or fifth harmonics of the ERS transmitted frequencies. MITRE performed the measurements at distances of 1, 2, and 3 miles from the ERS. At 1 mile, measurable ERS harmonic signals could be found on 5 of the 10 frequencies; on the other 5 frequencies, the ERS harmonics were so low that they were undetectable below the ambient noise level. At the 2-mile distance, only three of the ERS harmonics were above the noise; none of these was measurable at 1 mile, which suggests the expected randomness in the antenna pattern at the harmonic frequencies. At 3 miles, none of the harmonics was evident above the ambient noise.

The measurements suggest that there is about a 50% chance of harmonic interference in the low VHF land mobile band if the receiver is receiving a very weak signal and is only 1 mile from the transmitter. At a 2-mile distance, the chances have decreased to about 30%, and at 3 miles the chances are so very slight that the potentially interferring harmonics could not be measured. So far as is known, no actual interference with low-band VHF land mobile radio occurred, even though the Scott Paper company operated such communications equipment on a frequency near 50 MHz in the area within several miles of the ERS transmit site.

These results indicate that the ARS is also unlikely to produce interference to similar land mobile radio systems at distances greater than 3 or 4 miles.

During some ground-level power density measurements in June 1981, the measurement team coordinated frequency changes and beam steering using small, hand-held, portable VHF handy-talkies operating at 154.6 MHz (see Section B.8). No interference was ever noted. One portable unit was inside the transmitter building, using an external antenna. It communicated with the other, which was used directly behind the backscreen, at the end of the antenna array, and at a number of points along the exclusion fence, including points about 2,000 ft directly in front of the antenna array.

This test simply demonstrates that the radar does not necessarily interfere with radio communication in its immediate vicinity. The ERS frequencies used during this test included one near the midpoint of each of that radar's four bands; none of these, however, were subharmonics of the VHF handy-talky frequencies.

C.3.1.2.4 Effects on AM and FM Radio Reception

Operation of the ARS is not expected to interfere with reception of broadcast radio beyond about 2 miles from the transmit site. According to Abel (1981), MITRE monitored AM and FM radio broadcasts on an automobile radio at a number of locations along the ERS transmit site access road and along other roads near the transmit site while the ERS was operating. They determined that the ERS produced no interference in either the AM or FM broadcast bands at distances greater than about 1 mile from the ERS transmit antenna.

The ARS may produce interference to AM and FM radio reception at distances greater than did the ERS. First, its maximum output power is to be slightly greater than that used during testing of the ERS. Second, the atmospheric radio noise levels in rural Alaska will generally be lower than in Maine, which would permit reception of lower-level broadcast signals in Alaska than in Maine. Third, the ARS ground-wave signal will probably propagate further over thawed permafrost than over the rocky terrain of Maine.

Despite these factors, interference may not actually occur. Interfering with radio listening at any location requires that there be a signal there with which to interfere and also requires someone there trying to receive that signal. Thus, in sparsely-populated Alaska, far from the service areas of urban radio stations, interference may not actually occur.

C.3.1.2.5 Airborne Communication and Airnavigation Systems

C.3.1.2.5.1 Air-to-Ground Communications

When within radio line of sight of ground stations, aircraft use VHF frequencies, some of which are in the 118- to 132-MHz band. When at sea, beyond radio line of sight of ground stations, they are forced to use HF radio communications.

C.3.1.2.5.1.1 HF Air-to-Ground Communications

Because some aeronautical mobile bands are adjacent to the bands to be used by the OTH-B radar, aircraft flying at sea could be illuminated from above by the radar using a signal close to the aircraft's communication frequency. Abel (1980b) studied the matter to determine the guardbands necessary to prevent the ERS from producing adjacent-channel interference. He found that 16-kHz guardbands would sometimes be needed, although sometimes narrower guardbands would be adequate. These results depend on the radar's power level and on ionospheric propagation conditions and may be slightly different for the ARS.

C.3.1.2.5.1.2 VHF Air-to-Ground Communications

The VHF air-mobile communication frequencies in the 118- to 132-MHz band may be susceptible to fifth harmonics of the radar when it transmits on frequencies in the 23.6- to 26.4-MHz range and to sixth harmonics when it transmits between 19.67 MHz and 22.0 MHz. Abel (1980b) calculated that the ERS would not produce interference to airborne VHF receivers at distances beyond about 16 miles. Because the calculation had to be based on assumptions (regarding the harmonic suppression of the radar and the gain of the antenna at the harmonic frequencies) that could easily be in error by several decibels, the calculated distance could also differ considerably from what would actually be found. Although there is no indication that this 16-mile prediction was ever checked during the VOR tests described in the following subsection, no one complained of interference to airborne communications during the period of more than a year that the ERS was operated.

Two ground stations of the FAA's VHF air-ground communications network could be located only about 5 miles in front of the ARS transmit arrays, depending on where it is eventually built. These are the Paxon station, operating on 122.3 MHz, and the Tok station, operating on 122.4 MHz. Due to the terrain, either would probably be directly illuminated by the OTH-B signal, and the ground-based receivers would probably

behave similarly to an aircraft's at the same distance. Other stations, not so close to a possible ARS transmit site, are those at the Gulkana airport and a remote site near Mentasta Lodge. When the radar is built, tests could be conducted to determine whether the radar's subharmonics or other emissions cause interference to the FAA's remote VHF communications stations. If interference existed, the offending frequencies could be eliminated from the radar's complement of usable ones.

The ARS will have only slightly more available power than the ERS had during testing. If both radars were using their maximum available power, a given power density in the sky would be found at a distance from this radar about 1.15 times as great as from the ERS. Thus, although the ARS's potential for causing interference to airborne VHF communications is slightly greater, experience at the ERS suggests that such interference will not become a problem.

C.3.1.2.5.2 Air Navigation

Radio-operated aids to air navigation consist of equipment in the aircraft and ground stations maintained throughout the United States by the FAA. The nearest such ground station to the ARS study areas are at Gulkana, Northway, and Big Delta. Depending on the selected transmit site, aircraft using some of these systems will be illuminated by the ARS, and experience at the ERS suggests that interference to some systems would probably occur if the radar were to transmit on certain frequencies. These frequencies could be determined and either the radar could be forbidden to use them or the systems' frequencies changed.

C.3.1.2.5.2.1 VORTACs

C.3.1.2.5.2.1.1 Background

Aircraft can obtain bearing information from a VHF omnirange (VOR) transmitting station. Each VOR ground station operates in one of about 100 channels in the 108- to 118-MHz band (just above the FM broadcast band). The transmitter radiates signals that the receiver system in the aircraft can use to determine the bearing from the aircraft to the ground station. When a VOR is colocated with a military distance-measuring system called TACAN (for Tactical Air Navigation system), the combined facility, from which either a civil or a military aircraft can determine both its distance and its direction, is called a VORTAC. The TACAN portion of the VORTAC operates in the 960- to 1215-MHz band. VORTACs are widely used in Alaska, and the three VORTACs nearest the ARS study areas are listed in Table C-4 and are indicated on the map in Figure C-7. Under ideal conditions, a VOR can be used at distances to about 130 nautical miles (150 miles) by an aircraft at 18,000 ft, and at greater distances if the aircraft is at higher altitudes (FAA, 1968). Similar distances probably apply to the bearing-measuring part of the VORTAC.

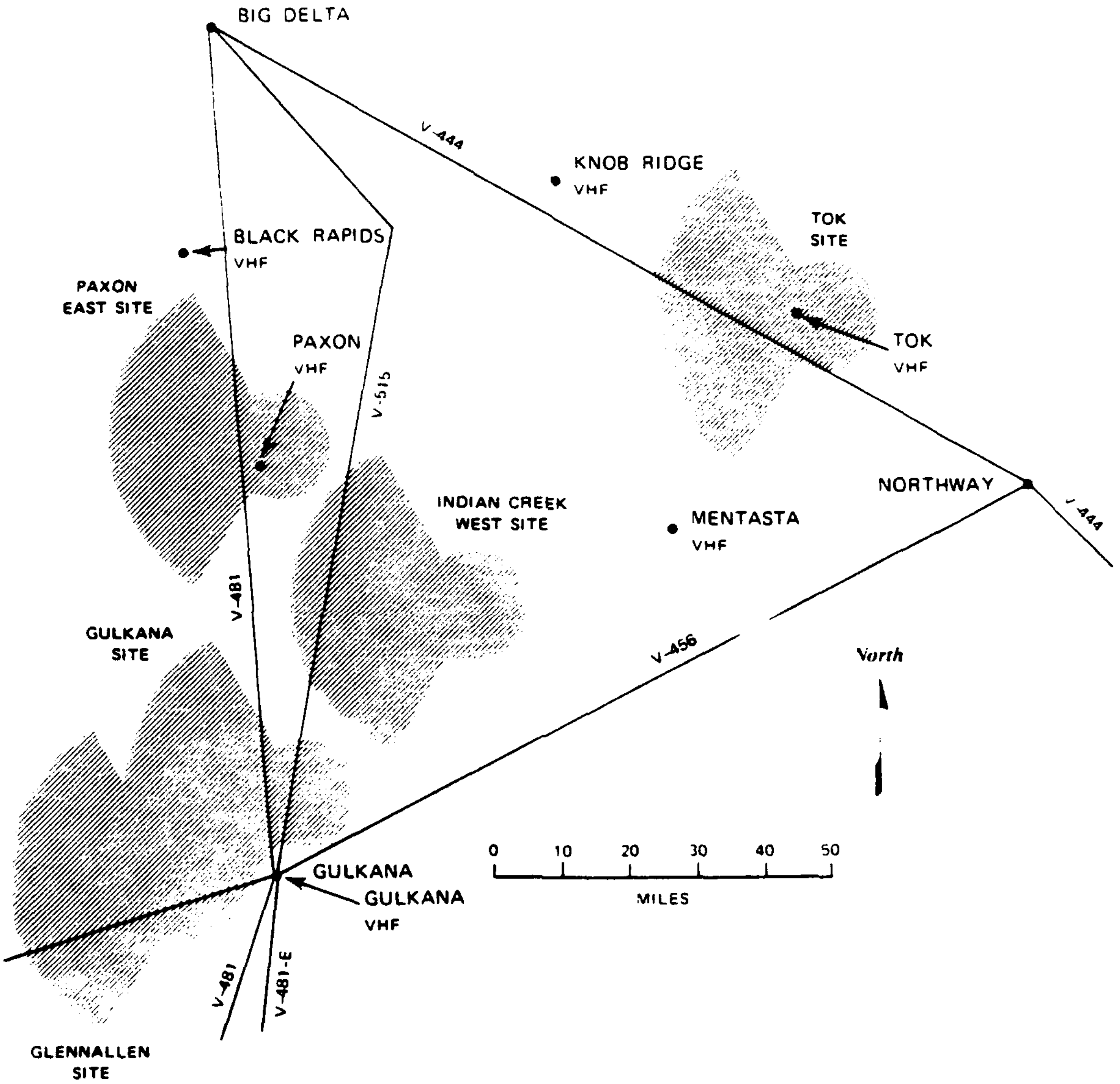


FIGURE C-7 LOW-ALTITUDE FEDERAL AIRWAYS AND AIR-GROUND COMMUNICATION STATIONS NEAR THE ARS STUDY AREAS

Table C-4

VORTACS WITHIN ABOUT
100 MILES OF THE ARS AREAS

Call Letters	Location	VOR Frequency (MHz)	Subharmonics (MHz) Fifth	Sixth
GKN	Gulkana	115.6	23.12	19.27
ORT	Northway	116.3	23.26	19.38
BIG	Big Delta	114.9	22.98	19.15

Source: U.S. Department of Commerce, 1985.

The map in Figure C-7 indicates the official air routes near the study areas. The routes (designated "V") shown interconnecting the three VORTACs are the Low Altitude Federal Airways that may be used at altitudes up to 18,000 ft above mean sea level (MSL). (They continue beyond the segments shown in the figure). These are all recognized routes, but aircraft flights are not limited to such routes, and aircraft will certainly be traversing this region on other routes. Furthermore, some aircraft are equipped with inertial navigation systems so that they are not reliant on the VORTAC system. Other aircraft may be using the non-directional radio beacons discussed later. Still others may be flying courses that require them to fly over terrain far from the official routes. In short, aircraft may be flying courses over any portion of the land near the study areas.

C.3.1.2.5.2.1.2 Experience with the ERS

Under some circumstances, an OTH-B radar can produce interference with an aircraft's VOR receiver if the radar is transmitting on or near frequencies that are subharmonics of the VOR's frequency (Abel, 1981)--that is, the harmonics of the radar may affect the receiver. The interference manifests itself by deviation of the VOR receiver's indicator needle, so that false bearings are obtained. Abel described two investigative measurement flight sequences. In the first, an aircraft leased by MITRE was flown along radials from the ERS site toward each of several VORs while the ERS transmitted on various permitted frequencies ranging from the sixth to the tenth subharmonics of the VORs involved. (Fifth subharmonics for the VORs in the vicinity of the ERS are at frequencies in band F, which was above the capability of the ERS.) MITRE found that the ERS caused oscillations of the indicating needle greater than ± 2° (or other false bearing readings) out to a maximum distance of 24 miles from the ERS transmit site.

The FAA conducted the next measurements, using its own instrumented aircraft. It flew three 360°-orbits around the ERS at a range of about 17 miles and an altitude of 5,000 ft while the ERS transmitted on frequencies as far as 8 kHz below the sixth subharmonic of a VOR about 45 miles away. The FAA determined that out-of-tolerance course errors (greater than 3°) occurred at a number of azimuths, generally in front of the radar. In another flight, the FAA followed a route directly away from a VOR about 60 miles from the ERS, approaching the ERS from behind and passing within about 6 miles of it. The ERS was transmitting on a frequency 1.67 kHz below the sixth subharmonic of the VOR. Course errors were less than 1° until the aircraft was about 8 miles from (and behind) the ERS. Course errors then became greater than 3° until the aircraft passed essentially into the region in front of the radar; there, the errors became so large that the VOR signal was unusable at distances out to about 26 miles. On yet another flight, the FAA followed a route that approached within about 25 miles of and essentially in front of the ERS while the ERS was transmitting on the sixth subharmonic of the VOR in use. No interference was noted in that case.

The Maine VORs did not have the additional distance-measuring capability that the Alaska VORTACs have, and so the experience obtained at the ERS has no bearing on the interference to be expected in aircraft using distance-measuring equipment (DME) that receives the VORTAC's UHF signals. The airborne DME may also be susceptible to the radar's harmonics, but no theoretical study or measurement is known to have treated this subject.

C.3.1.2.5.2.1.3 Probable Effects near the ARS Transmit Site

The map in Figure C-7 shows the location of the five ARS study area sites along with the region in which the radar might be expected, from the ERS experience, to cause interference to aircraft VOR receivers if it were transmitting on or very near the sixth subharmonics of the three local VORTACs. The fan-shaped 120°-region extends 26 miles "in front of" the radar, and the smaller-radius 240° region extends 8 miles "behind" it. Because the ARS, unlike the ERS, will include band F (22.25-28.00 MHz) in addition to the others, interference could also occur when the radar transmits on the VORTAC's fifth subharmonic. (The fifth and sixth subharmonics are listed in Table C-4.)

The map also indicates the instrumented air routes, and Table C-5 indicates approximate distances from the study areas to each route's point of closest approach. Thus, depending on the selection of the transmit site, various routes could potentially be affected.

Table C-5

APPROXIMATE DISTANCES BETWEEN
ARS STUDY AREAS AND AIR ROUTES
(miles)

Study Area	Low-Altitude Federal Airway			
	V-444	V-456	V-481	V-515
Glennallen	> 50	2 f	12 b	13 b
Gulkana	> 50	8 b	6 f	3 f
Indian Creek	> 50	23 b	32 f	21 f
Paxon East	48 b	> 50	6 f	11 b
Tok	8 f*	38 b*	> 50	> 50

*The "f" and "b" indicate that the air route passes either in front of (f) or behind (b) the study area.

Because the ARS, unlike the ERS, will include band F (22.25-28.00 MHz) in addition to the others, interference could also occur when the radar transmits on the VORs' fifth subharmonic. The distances from the radar at which fifth-harmonic interference would occur could be predicted using broad assumptions regarding the radar transmitter output power at the harmonic frequencies and the gain and pattern of the transmit array at these harmonic frequencies (far removed from the radar's intended operating frequencies). Such assumptions, however, could easily be in error by a factor of 10 dB, and in predicting distances at which an interference effect will take place, a 10-dB error translates into a multiplying (or dividing) factor of about three in a predicted distance. Knowing, from the experience with the ERS, that such interference can occur, the Air Force could include both the fifth and sixth subharmonics of the nearby VORs in the list of forbidden transmit frequencies. Alternatively, the FAA could choose to change VOR frequencies so that their subharmonics would not even be used by the radar. The Air Force would cooperate with the FAA in determining the necessity and nature of any mitigation measures. The Air Force would also help by participating in FAA test flights designed to determine whether interference exists initially or following any mitigating measures. Such tests could also evaluate any effects to the DME receiving system on the aircraft, which did not apply to the air navigation equipment near the ERS in Maine.

C.3.1.2.5.2.2 Non-Directional Beacons

Three airports in the area (Glennallen, Delta Junction, and Northway) are served by NDBs. These NDBs are also sometimes known as compass locators and are probably the simplest radio aid to air navigation. Each NDB broadcasts omnidirectionally a coded identifying signal on a frequency in the 200- to 1,600-kHz band. The aircraft carries a direction-finding system, by which it can determine the direction from the plane to the beacon. The NDB's antenna pattern includes a vertically directed null, so that when an aircraft passes directly overhead, there is a sharp decrease in signal strength; this provides the pilot with a definite fix on his position.

We do not know whether any tests have been conducted specifically to determine the effect of the OTH-B signal on the airborne direction finding receivers. However, the effects of the OTH-B signal would be very similar to those that would be experienced when a plane using an NDB signal passes close to any large HF transmitting system, such as those used by Voice of America and other users of the International Broadcast band. The situation would not be unique to the OTH-B radar.

C.3.2 Hazard Effects

This section discusses the potential effects of the OTH-B electromagnetic fields on equipment other than telecommunication systems. They are termed "hazard effects" because they describe three potentially dangerous situations that high-amplitude RF fields can cause under certain circumstances: (1) interference with the normal operation of implanted cardiac pacemakers, (2) accidental detonation of electro-explosive devices (EEDs), and (3) ignition of liquid fuels as they are being handled. Besides pacemakers, other implanted or attachable medical prosthetic devices exist, but they are principally in the developmental or prototype stage, and little information is available on their susceptibility to interference. These newer implantable devices are expected to have the same resistance to interference as modern pacemakers (Toler, 1982).

C.3.2.1 Cardiac Pacemakers

Cardiac pacemakers are potentially subject to EMI, making it is possible that the OTH-B radar could affect pacemaker owners in its vicinity in the air or on the ground. Whether the OTH-B radar will affect a pacemaker depends on the susceptibility of the individual device and on the level of the OTH-B signal that reaches it. Although very few directly applicable susceptibility data are available from which to make exact predictions of the hazardous regions for a pacemaker owner, existing data suggest that the region is quite small and well within the proposed exclusion fence. The likelihood is very small that a pacemaker owner, either on the ground or in the air, would enter a potentially dangerous region or could remain there long enough to be affected. Thus, the possibility of interference is remote.

C.3.2.1.1 Background

The heart can be considered to be an electrically operated pump. It is a set of muscles that contract rhythmically in response to a periodic electrical impulse that originates naturally in a certain portion of the cardiac tissue. Some people who suffer impaired operation of that natural pacemaker or of the conducting paths in the cardiac tissue rely on an artificial pacemaker, which supplies the electrical signal to make the heart beat when it should. Hundreds of thousands of people in the United States have pacemakers.

Four general types of cardiac pacemakers are employed, but by far the most common (80 to 90% of the pacemakers in use) is the R-wave-inhibited type. The R-wave-inhibited (synchronous) pacemaker supplies a pulse only on demand (i.e., when the heart requires it) and is often called a demand pacemaker. It senses the naturally occurring electrical signal of the main pumping action of the heart. If that fails to occur when it should, the pacemaker supplies the signal to trigger the heart's action. Although R-wave-inhibited pacemakers are generally more susceptible to EMI than the other types are, great progress has been made in recent years in reducing that susceptibility.

Pacemakers do not fail permanently when exposed to strong RF fields; instead, if the field is sufficiently intense, they may exhibit one of four types of dysfunction, of which the most common (for a synchronous pacemaker) is termed "reversion." This means that the pacemaker reverts to a benign fixed rate; it is designed to respond to RF by becoming, for the time being, an asynchronous pacemaker. Reversion is not always even considered a form of dysfunction. In fact, for purposes of monitoring the pacemaker's fixed rate (and thus the battery condition), a pacemaker owner frequently will deliberately cause his pacemaker to assume that condition.

C.3.2.1.2 Susceptibility to RF Fields

Most available data on the susceptibility of pacemakers have been developed at radio frequencies well above the HF band or at the AC power frequencies of 50 Hz, 60 Hz, and 400 Hz. The AC power frequencies were chosen for experiments because exposure to them is virtually unavoidable; everyone is exposed daily to fields or to physical contact with devices radiating at these power frequencies. At RF, a pulse-modulated 450-MHz signal "was selected as a compromise frequency that represents good body penetration and has been used by expert personnel in the field" (AAMI, 1975). Between 400 Hz and 450 MHz is a very large frequency range on which very few data have been published; measurements in that range are conducted only for special purposes, such as when the safety of pacemaker owners in the vicinity of some specific device or system is of concern.

The modulation of the RF field largely dictates whether and how a field will affect a pacemaker. Pulse modulation is the form of modulation most likely to affect a pacemaker, because the pacemaker is designed to sense electrical pulses, and a threshold of field intensity exists

above which a given pacemaker will react to external RF pulses. According to Denny, Jenkins, and Toler (1977), at low PRFs (less than 10 pps) an R-wave-inhibited pacemaker is likely to misinterpret such pulses as the heart's electrical activity and to become inhibited. At higher PRFs, the pacemaker is more likely to revert to asynchronous operation. Long-term inhibition (for durations greater than about five normal heartbeats) may constitute a health hazard for some owners, whereas reversion to fixed-rate pacing is less serious. One writer has stated that "frequency or phase modulation does not affect the pacemaker" (Schlentz, 1975). The OTH-B's modulation is a form of frequency modulation.

Although considerable research was conducted and many papers were published on pacemaker susceptibility to electromagnetic fields in the middle and late 1970s, this activity has greatly decreased. The principal reasons are that the Association for the Advancement of Medical Instrumentation (AAMI) developed a draft pacemaker susceptibility standard in 1975 (AAMI, 1975) and, in accordance with that draft standard, the pacemakers now being marketed are capable of unaffected operation in 450-MHz pulsed field strengths in excess of 200 V/m. (This implies that they would also almost certainly be capable of unaffected operation in a frequency-modulated field of 200 V/m.) That 1975 draft standard also required that the pacemaker be unaffected by CW (unmodulated) power-frequency signals directly coupled to the pacer at a 100-mV level. Susceptibility testing has now become routine; the Biomedical Research Division of the Engineering Experiment Station of Georgia Institute of Technology conducts that work for all but one of the major U.S. manufacturers, as well as for many of the major foreign manufacturers (Toler, 1982).

A later (November 1981) draft version of the AAMI pacemaker standard describes various performance tests, but all references to EMI susceptibility testing have been dropped. According to a cochairman of the AAMI pacemaker committee, this was done for two reasons. One was to make the U.S. standard more similar to an international standard so as to facilitate trade. The other reason was that the committee believed that a rigid electromagnetic compatibility standard could encourage manufacturers to produce pacemakers with EMI susceptibility no better than the minimum requirements of the standard (Flink, 1982). Mr. Flink agrees that the modern pacemakers are almost invulnerable to EMI.

Susceptibility levels, based on pulsed 450-MHz tests in August 1975, were published by Mitchell and Hurt (1976). That report states that the susceptibility levels (ranging from 4 V/m to more than 260 V/m) "are believed most representative of the current state of technology" (for 1975). The report also states that "if pacemakers were designed and tested to be compatible with the minimum E-field level, viz 200 V/m, associated with the unrestricted 10 mW/cm^2 personnel exposure level, potential EMI situations would be substantially reduced or effectively eliminated." Such a 200-V/m testing level, described in the 1975 standard prepared by the AAMI for the FDA, is now in general use. Schlentz, Larson, and Exworth (1976) had shown that results of tests

with the pacemaker immersed in saline solution to simulate body tissue were entirely equivalent at 450 MHz to results using implanted pacemakers. The field strengths are defined and measured in the air outside the body or the saline solution. With the pacemaker submerged in the tank of saline solution, its catheter is aligned for maximum coupling with the electromagnetic field. Testing is to be done at, but not necessarily above, 200 V/m within 50 MHz of 450 MHz and at pulse repetition frequencies of 125% ± 10% of the basic rate of the pacemaker.

The only known measurements that indicate the susceptibility of pacemakers to RF fields in the HF band were conducted by the Air Force in 1977 (Hardy, 1979). In addition to pulsed signals at other frequencies, Hardy worked with a CW signal at 26 MHz, which would probably be very similar to the OTH-B linear FM/CW signal. Hardy's pacemakers were immersed in saline solution, which is also the method recommended in the 1975 standard and currently used by workers at Georgia Institute of Technology. Hardy reported on 26-MHz CW measurements using 30 pacemakers, of which 17 were unaffected by fields as high as 850 V/m--the maximum field available from the test system. The susceptibility thresholds of the other pacemakers ranged from 230 V/m to 850 V/m.

Both Mitchell (1978) and Denny (1978) suggested that the manufacturers were then probably meeting the 200-V/m level in their newer models. The 1977 measurements reported by Hardy in 1979 indicated that many were not susceptible to 450-MHz pulsed signals with levels as high as 330 V/m. Denny stated in 1978 that the threshold for most of the newly released pacemakers was above 300 V/m. Toler believed that none of the pacemakers being released by 1982 were susceptible to pulsed fields of 200 V/m.

Manufacturers contacted in an informal 1978 survey for the EIS for the PAVE PAWS (420- to 450-MHz) radar at Beale AFB stated that their newer pacemakers met the 1975 AAMI standard, and one manufacturer said that the manual for a particular model stated that it had been tested to 295 V/m.

By now (1986), probably none of the older pacemakers described in the literature of about 10 years ago would still be functioning; thus the susceptibility thresholds of the pacemakers currently in use is probably quite high. The reason for the rapid replacement of the older pacemakers with the newer ones is that an entirely new pacemaker must be implanted when the battery becomes exhausted; the physician then has an opportunity to implant a pacemaker less susceptible to EMI. When the mercury cell was the only type of battery used, pacemaker replacement was necessary about every 2 to 3 years; lithium iodide batteries last 6 to 8 years or more and are now essentially the only type used.

C.3.2.1.3 Susceptibility to OTH-B

Pacemakers are apparently not particularly susceptible to signals in the HF band. Because the OTH-B signal is essentially continuous (and

not pulsed), the pacemaker does not confuse it with the naturally occurring electrical signals that the pacemaker is designed to sense. The data available suggest that modern pacemakers would be affected by OTH-B fields only if the fields were well over 200 V/m. The curves shown on Figures B-5 through B-10 can be used to define a "safe" distance; beyond that distance, fields exceeding 200 V/m will not exist. Because more than one-half of Hardy's pacemakers were unaffected at 850 V/m and none were affected by fields as low as 200 V/m, the 200-V/m standard results in a very conservative estimate of safe distance.

At ground level in front of the radar, fields will fall below 200 V/m at a distance of about 1,300 ft from the center of the array. Section B.6 of Appendix B indicates that fields of 200 V/m will not exist at all behind the array. If the exclusion fence were located about 4,000 ft in front of each array the casual pacemaker owner approaching the radar would not be subjected to fields exceeding about 45 V/m, and so the radar should present no hazard.

In the sky in front of the radar, on the axis of the main beam, the fields would fall below 200 V/m at a slant range of about 1,300 ft. The main beam axis at this distance is at a height of about 400 ft; the horizontal beamwidth is about 200 ft, and the beam shifts horizontally from time to time. Above or below the 400-ft height or outside the nonstationary 200-ft wide beam, the field would be lower. This region of airspace is at a horizontal distance of just over 1,100 ft from the array and is above the land enclosed by the exclusion fence; thus, a pacemaker owner is highly unlikely to enter this small piece of airspace or to be able to remain in it for long.

Although operation of the radar could not be considered to constitute a hazard to pacemaker owners, the Air Force will request that the FAA publish an appropriate Notice to Airmen (NOTAM) warning fliers not to approach the radar too closely. Such NOTAMs have been published for other Air Force radars.

C.3.2.2 Fuel Handling

The military has long been concerned over the possibility that high-powered radars (such as those on an aircraft carrier) could ignite volatile fuels as they are transferred. Ignition would result if the high RF fields caused a spark across a gap in a fuel-air mixture that had certain proportions. Researchers have determined the DC spark energy required to ignite fuel; according to Air Force Technical Manual T.O. 31Z-10-4 (1971), "The amount of RF voltage required to break down a similar gap is unknown but is believed, until proven otherwise, to be approximately the same as the dc-voltage value." For fuel handling near a radar, "a peak power density of 5 W/cm^2 (5,000 mW/cm^2) or less can be considered safe."

For the OTH-B radar, which would not pulse like a typical radar, but would operate continuously, the "peak" power density and the average power density are equivalent, providing that the average is taken over a

time duration no greater than the dwell time that the radar's beam is directed toward any given sector. Because any gap-breakdown effect would take place in milliseconds, or possibly microseconds, our concern must be with the radar's peak power density rather than with the long-term average power density used in Appendix B. There, the averaging considers that a given array's beam is equally likely to be directed toward any one of the array's eight 7.5° surveillance sectors. Table B-2 and Figures B-5 through B-10 show that the "peak" OTH-B power density, even in the near-field column, never exceeds about 258 mW/cm^2, which is a factor of almost 20 lower than the maximum safe power density of 5,000 mW/cm^2.

The OTH-B radar will not pose a hazard to existing or planned fuel-handling operations.

C.3.2.3 <u>Electroexplosive Devices</u>

C.3.2.3.1 <u>Types of EEDs</u>

EEDs are used to activate secondary explosive charges, to ignite propellant systems, and to actuate electroexplosive switches. A common electric blasting cap is one form of EED. EEDs are used in aircraft systems to jettison flares and wing tanks while the aircraft is in flight, to release externally carried missiles, and, in some aircraft, to activate ejection seats. Still other applications exist, and the use of EEDs on modern military aircraft is common. The following are the four basic types of EEDs, actuation mechanisms, and uses (Hovan, 1978):

- Exploding bridgewire--This type requires a high-energy capacitive discharge pulse to explode bridgewire.

- Normal bridgewire--An explosive mix is glued to the bridgewire; electrical current heats the bridgewire, detonating the adhesive primer.

- Composition mix--This type uses conductive explosive mix; the current passes through the mix, igniting it.

- Carbon bridge type--This type is used internally in 3 or 4 weapons systems and in 20-mm cartridge primers.

All EEDs are ignited electrically and hence are subject to accidental ignition from the following causes:

- Lightning discharge--Lightning protective systems normally preclude the inadvertent ignition of EEDs by direct lightning strikes.

- Static electricity discharge--This is a hazard mainly in ground operations.

- Stray energy, such as transients and other forms of induced conducted energy, from other on-board electrical equipment.

- Radiated fields from RF emitters--If the RF field is strong enough, it can induce currents that will cause the EED to fire.

C.3.2.3.2 Electromagnetic Field Safety Standards for EEDs

EEDs are susceptible to ignition by exposure to radiated fields. The degree of susceptibility depends on many variables: the safe no-fire threshold of the EED, the ability of the EED leads to capture RF energy, the frequency and power density of the RF energy, and the condition of exposure of the EED--whether contained in a shielded cannister, mounted inside an aircraft with shielding provided by the skin of the aircraft, or exposed to the environment with no shielding present.

Although we are aware of the potential hazard to EEDs such as blasting caps,

> "From a practical standpoint, the possibility of a premature explosion due to RF energy is extremely remote. This has been demonstrated by numerous tests on representative transmitting equipment, and it is confirmed by many years of experience. The annual consumption of electric blasting caps is well over 100 million, and they are used in every section of the country. Yet there have been only two authenticated cases of a cap being accidentally fired by radio. Both these were caused by amplitude-modulated (AM) transmitters operating in the low frequency range (540-1600 kilocycles) with horizontal antennas" (State of Maine, 1976).

C.3.2.3.2.1 The Air Force Standard for Safe Exposure Limits

The Air Force safe exposure criterion is expressed either as a safe average power density, in W/m^2, or as a safe separation distance. As the distance, d, between an EED and the RF transmitter is increased, the power density at the EED decreases at least as rapidly as $1/d^2$.

The safe separation distances specified by the current version of Air Force Regulation (AFR) 127-100, Explosive Safety Standards (USAF, 1983) are said to be based on a worst-case situation--that is, on the most sensitive EED currently in inventory, unshielded, and having leads or circuitry that could inadvertently be formed into a resonant antenna. The criteria apply generally to critical areas involving explosives assembly, disassembly, testing, loading, and unloading operations, and are based on the safe, no-fire threshold of the EED. This is intended to be a very conservative safety threshold, and exceeding it does not imply that the EED will fire. The actual firing threshold of the EED may be several orders of magnitude above the safe no-fire threshold.

Table C-6 summarizes the AFR 127-100 criteria for safe power flux density exposure for EEDs in several configurations. All safe exposure limits are given in terms of average power density in the 2- to 48.5-MHz frequency range.

Table C-6

SAFE EXPOSURE LIMITS FOR EEDs AT OTH-B FREQUENCIES

Exposure or Storage Condition for EED	Average Power Density* W/m^2	mW/cm^2
EEDs in exposed condition (also applies for any "unknown worst case" situation).	0.01	0.001
EEDs in storage or transport, in metal containers, leads shorted	100	10
EEDs in storage or transport, in nonmetallic containers, leads shorted	0.1	0.01
Aircraft parked or taxiing with externally loaded weapons	1.0	0.1
Aircraft in flight with externally loaded weapons, or shipment of EEDs inside cargo aircraft	100	10
Leadless EEDs in original shipping configuration	(No maximum power density; minimum distance; 10 ft)	

*1 w/m^2 is Oil mW/em^2

Source: USAF, 1983.

The ground-level safe-distance predictions in this subsection are based on estimates of ground-wave power density, which themselves are based on estimates of the ground conductivity in the study areas. A relatively high ground conductivity, thought to be applicable to summer permafrost conditions, was used, which may result in predictions of high power density at greater distances than will actually occur, and therefore of very large regions where transporting, storing, and/or handling EEDs are not guaranteed to be safe. The safe separation distances obtained through this extremely conservative approach are greater than would be found using lower, but still reasonable, values for the ground conductivity in the power density predictions. Also, of course, when

the soil freezes in winter, the conductivity would decrease, and safe-separation distances established for summer conditions would become even safer.

Figure C-8, taken from the plots of Figures B-5 through B-10 of Appendix B, compares some safe exposure limits with estimated OTH-B power densities that could occur in the vicinity of the ARS in the summer. The ground-wave power densities here were calculated using an assumed ground conductivity that ranged from about 0.13 S/m at the lowest band to about 0.16 S/m at the highest band. Lower assumed ground conductivity would yield lower power density at a given distance, and the power density at a given location will be lower in winter than in summer. If the ground conductivity were known precisely, such curves would allow the accurate determination of the corresponding safe exposure distances. The sky-wave curve is the same for all six bands. The ground-wave curve differs from band to band, however. The two higher frequency bands (E and F) have a greater ground-wave power density close to the array because they are both vertically polarized, in contrast to the 45° polarization of the other bands. Because higher-frequency power density falls off more rapidly with distance than does that of the lower frequency bands, the power density of the lower frequency bands is greater at the greater distances. Thus, for a specific exposure limit, the most conservative approach is to consider the band that provides the greatest safe distance.

Curves are provided for the regions in front of the radar and behind it. The "front" of the radar is a 120° arc centered approximately due west; "behind" is everywhere else. Although the uppermost curve is labeled sky wave, the power densities there are simply the main beam power densities; if there were any mountain tops to be brushed by the main beam, that upper curve would be more applicable than the ground-wave curve.

The figure indicates that the OTH-B radar presents no hazard to EEDs stored or being transported in metal containers at ground level at distances beyond about 1,300 ft from the array center, where bands E and F predominate. So far as is known, only military aircraft are likely to be equipped with EEDs. Aircraft in flight that carry or are equipped with EEDs, would be beyond the hazardous area if they were at a slant range of more than about 1,300 ft from the front of the radar. The NOTAM mentioned in Section C.3.2.1.3 will warn fliers against approaching the radar.

EEDs stored or being transported at ground level in nonmetal containers would be safe even in the summer at distances greater than roughly 3.4 miles from the front of the radar or about 3,000 ft behind it.

Exposed EEDs, such as blasting caps being handled in preparation for a blasting operation in summer, would be safe if removed to about 6.3 miles. If the ground conductivity is not as high as our estimate,

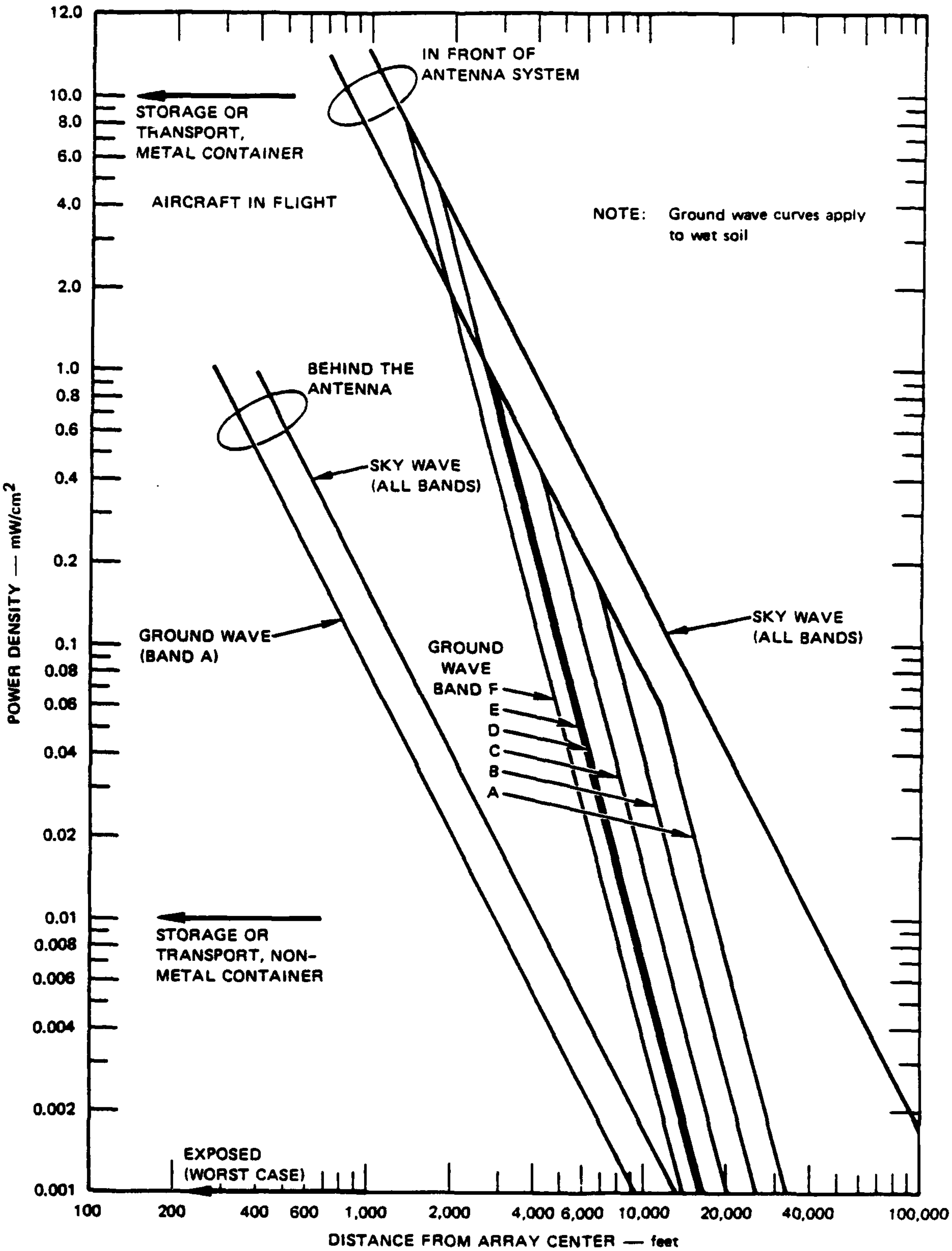


FIGURE C-8 OTH-B POWER DENSITIES AND SOME SAFE EXPOSURE LIMITS FOR EEDs

the safe distance would be closer to the radar. If EEDs were used on an exposed mountain, however, the safe distance would be as far as about 25 miles.

Ground conductivity measurements would permit more accurate estimates of the ground-wave power density, and therefore more accurate determination of the safe separation distances.

C.3.2.3.2.2 Explosives Manufacturers' Recommendations for Blasting Caps

The use and handling of electric blasting caps are specifically addressed in a publication by the Institute of Makers of Explosives (1981). The publication does not provide safe exposure limits in terms of power densities, but rather recommends safe distances from common classes of RFR emitters; in some cases the distance is given as a function of transmitter power or effective radiated power (the product of the transmitter power and the antenna gain). The evaluation that most closely approximates the OTH-B situation is a curve of "recommended distances from transmitters up to 30 MHz (excluding AM broadcast)" and applicable to "International Broadcast Transmitters in the 10-25 MHz range." Such transmitting systems, including the OTH-B system, are intended to launch a sky wave; ground-wave power is an unavoidable by-product. The curve therefore shows the safe distance as a function of the power that the transmitter puts into the antenna, not as a function of the power that the antenna array radiates in the sky wave. For simplication, the manufacturers' safe-distance curves do not take differences in ground conductivity into account, and appear to be conservatively based on the assumption of a very high conductivity. If we use a transmit power of 1.2 MW, the safe region would appear to begin at about 90,000 ft (17 miles), which would agree with the Air Force standard based on power-density estimates made using an extremely high ground conductivity.

C.3.2.3.3 Safe Regions Near the CRS Transmit Site

When the location of the transmit site has been determined, and when ground conductivity has been measured, it will be possible to determine more precisely the safe distances mentioned in Section C.3.2.3.2 related to the specific terrain features such as roads and buildings at the selected site. The Air Force will then notify all affected land owners and state and local government offices so that they can take any actions, such as making notifications or posting, that they deem appropriate.

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Appendix D

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE ALASKAN RADAR SYSTEM

Appendix D

SIGNIFICANT ENVIRONMENTAL LAWS AND REGULATIONS PERTAINING TO THE NATURAL ENVIRONMENT AFFECTED BY THE ALASKAN RADAR SYSTEM

Regulatory Agency	Act/Regulation/Law	Regulated Resource	Description	Requirements
Federal				
All federal agencies	Section 810, Alaska National Interest Lands Conservation Act of 1980 (ANLICA)	Subsistence Activities	Section 810 of ANILCA requires that federal decisions on whether to withdraw, reserve, lease, or otherwise permit the use, occupancy, or disposition of public lands must be based on consideration of the impact of the decision on subsistence uses.	If agency action would significantly restrict subsistence uses, a finding must be made that the action is necessary and consistent with sound management principles, it would involve the minimal amounts of land necessary, and reasonable steps would be taken to minimize impacts on subsistence resources.
All federal agencies	Executive Order 11990 Protection of Wetlands, May 24, 1977; and Executive Order 11988, Floodplain Management, May 24, 1977	Wetlands	Precludes development in wetland or floodplain unless no practicable alternative exists and only after effective mitigation measures are developed.	Agencies must adhere to executive orders in their decision-making process.
All federal agencies	American Indian Religious Freedom Act of 1978	Cultural Resources	Provides federal policy to protect American Indians' right to practice their traditional religions, including access to sites and sacred objects.	Section 2 requires consultation with native traditonal religious leaders to protect Native American religious cultural rights and practices.

Regulatory Agency	Act/Regulation/Law	Regulated Resource	Description	Requirements
Advisory Council on Historic Preservation	National Historic Preservation Act of 1966, as amended (16 USC 470)	Cultural Resources	The intent of the Act is to ensure that no significant archeological or historical properties are irretrievably lost as a result of federally funded construction projects.	Section 106 requires that Federal Agencies must take into account the effect of a federally funded project upon any historic or archeological property listed or eligible for listing in the National Register.
Army Corps of Engineers	Section 404, Federal Water Pollution Control Act of 1972, as amended in 1977 (Clean Water Act) (33 USC 1344).	Streams, Lakes and Wetlands	Controls discharge of dredged or fill material into waters of the United States and adjacent wetlands.	Section 404(b)(1) of the Clean Water Act requires that the Corps of Engineers evaluate the proposed activity under guidelines prepared by EPA. The guidelines restrict discharge into an aquatic area where less environmentally damaging, practicable alternatives exist. If there are no substantial objections to the proposed activity, a permit is issued.
Environmental Protection Agency	Section 402 of the Federal Water Pollution Control Act	Water Quality	EPA is authorized to issue National Pollutant Discharge Elimination System (NPDES) permit for point source discharges to waterways.	The owner/operator must apply for an NPDES permit at least 180 days prior to commencing discharge.

Regulatory Agency	Act/Regulation/Law	Regulated Resource	Description	Requirements
Environmental Protection Agency (EPA)	Clean Air Act	Air Quality	Establishes New Source Performance Standards which apply to construction and operation of any source of air pollution for which standards have been issued.	The power plant or operator must ensure compliance with New Source Performance Standards to EPA.
Environmental Protection Agency	Section 311 of the Federal Water Pollution Control Act	Water Quality	The EPA requires that spill prevention and control plans be developed for onshore and offshore non-transportation related oil storage facilities which exceed specified volumes.	The owner/operator must develop a Spill Prevention Containment and Countermeasure (SPCC) Plan within six months after operations begin.
Department of the Interior Fish & Wildlife Service (FWS)	Fish and Wildlife Coordination Act of 1958 (FWCA)	Fish and Wildlife	Requires that wildlife conservation be given equal consideration and be coordinated with other features of water resources development projects.	Section 662(a) requires consultation with FWS and the state wildlife agency whenever waters of any stream are modified for any purpose.
Department of the Interior Fish & Wildlife Service (FWS)	Section 7, Endangered Species Act of 1973, as amended (16 USC 1531)	Fish, Wildlife and Plants	Section 7(a) of act requires that Federal Agencies ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of endangered or threatened species or adversely affect or destroy habitats of of species.	Informal consultation between Federal Agency and FWS must be undertaken if listed species or their habitats are believed to be present in area of proposed action. Preparation of biological assessment and formal consultation may be required.

Regulatory Agency	Act, Regulation/Law	Regulated Resource	Description	Requirements
Council on Environmental Quality (CEQ)	National Environmental Policy Act of 1969; Executive Order 11514 as amended by Executive Order 11991	All Components of the Potentially Affected Environment	Act establishes that environmental amenities and values be given appropriate consideration in decision-making, along with economic and technical considerations.	Section 1507.3 of CEQ regulations requires each Federal Agency to adopt procedures to implement NEPA in accordance with CEQ regulations. AFR 19-2, "Environmental Impact Analysis Process" specifies internal Air Force procedures.
Department of the Interior	43CFR.7 Uniform Regulations under the Archeological Resources Protection Act of 1979	Cultural Resources	Ensures that appropriate and qualified persons are allowed to use public lands for archeological and historical investigations.	Cultural Resource use permits are issued by the Bureau of Land Management after reviewing the qualifications of the person responsible for the investigation.
Department of the Interior	Historic Sites, Building and Antiquities Act of 1935	Cultural Resources	Federal Agencies are responsible for considering the existence and location of natural landmarks when assessing effects of their actions in the environment.	Proponent should check with National Park Service determine if any sites on the National Registry of Natural Landmarks are in proposed area of activity. Environmental analysi should consider alternative plans.

Regulatory Agency	Act/Regulation/Law	Regulated Resource	Description	Requirements
State				
Department of Environmental Conservation (DEC)	Alaska Statue 46.03, State Air Quality Regulations (18AAC50)	Air Quality	To prevent, abate and control air pollution in the state, DEC is authorized to issue permits for any air contaminant emission from a major source.	Applicant is required to submit application for Air Quality Control Permit to Operate, addressing facility plans and specifications, a description of air quality control devices, and an evaluation of air emissions effects on the ambient environment.
Department of Environmental Conservation	Alaska Statue 46.03, State Air Quality Regulations (18AAC50), Clean Air Act Amendments to Prevent Significant Deterioration (PSD)	Air Quality	DEC in authorized to issue PSD permits for construction of designated sources which will emit 100 tons per year of any air pollutant and all other sources which will emit more than 250 tons per year.	Applicant is required to submit letter to DEC which demonstrates that the proposed facility will not violate PSD increments, will not cause violation of National Ambient Air Quality Standards, and will employ the Best Available Control Technology.
Department of Environmental Conservation	Alaska Administrative Procedures (18AAC15), Section 401 of the Clean Water Act	Water Quality	A Water Quality Certificate from DEC is required to assure that discharges to navigable waters meet Alaska's Water Quality Standards.	The application for an Army Corps of Engineers permit (see above) will automatically trigger a request for the Certificate.

Regulatory Agency	Act/Regulation/Law	Regulated Resource	Description	Requirements
Department of Environmental Conservation	Alaska Statute 46.03 and 16.10, Alaska System Plan Review Regulations	Water Quality	DEC will conduct a Plan Review for sewerage systems and water and wastewater treatment works to protect public health and ensure compliance with state Water Quality Standards.	Engineering reports, plans and specifications must be submitted to, and approved by, DEC prior to starting construction.
Department of Environmental Conservation	Alaska Statute 46.03, Alaska Solid Waste Management Systems	Surface and Groundwater	DEC is authorized to issue a Solid Waste Disposal permit to anyone who constructs, modifies or operates a solid waste disposal site.	A permit application, including detailed reports, plans, and specifications on the facility and an evaluate of the site's leachate generation and water pollution potential, must be submitted to DEC at least 60 days prior to commencement of operations.
Department of Environmental Conservation	Alaska Statute 46.03, Alaska Wastewater Disposal Regulation	Water Quality	DEC is authorized to issue a Wastewater Disposal Permit to any person conducting an operation which results in the disposal of wastewater into or upon the waters or surface of the land of Alaska.	A permit application, including specific information on the treatment process and disposal site, must be submitted 60 days prior to commencement of operations.

Regulatory Agency	Act/Regulation/Law	Regulated Resource	Description	Requirements
Department of Fish and Game (DF&G)	Alaska Statute 16.05.870, Alaska Regulation on Waters Important to Anadromous Fish (5AAC95.010)	Anadromous Fish	DF&G is authorized to issue a permit for construction of a hydraulic project or alteration of a specified anadromous river, lake or stream.	The applicant shall submit to DF&G a Waterway/Waterbody Use Request and project plan and specifications, including the project schedule and methods and equipment to be used.
Department of Natural Resources (DNR)	Alaska Statute 38.05, Alaska Land Use Regulations (11AAC96)	Natural Environment	To protect the natual environment of the state-owned land, DNR is authorized to issue a Land Use Permit for surface equipment on state-owned land.	A permit application, including maps and descriptions of proposed activities and equipment, must be submitted to DNR's Division of Land and Water Managment.
Department of Natural Resources	Alaska Statute 46.15.030-.185, Alaska Water Use (11AAC72)	Water Supply	Appropriation of waters of the state requires a Water Rights Permit and a Certificate of Appropriation.	A permit application including loc**a**tion, quantities and proposed uses of the water source, must be submitted to DNR's Division of Land and Water Management. A certificate is issued after appropriation commence.
Department of Natural Resources	Alaska Statute 41.35, Alaska Regulation on Historic, Prehistoric and Archeological Resources (11AAC16)	Cultural Resources	The purpose of the Field Archeology Permit is to preserve and protect public historic, prehistoric, and paleontogical sites and objects of interest on state owned or controlled land.	A permit application form, including site maps, proposed activities, survey plan and qualifications of investigators, must be submitted to DNR's Division of Parks.

Appendix E

COMMON NAMES AND SPECIES NAMES FOR PLANTS, BIRDS, FISH AND MAMMALS

Appendix E

COMMON NAMES AND SPECIES NAMES OF PLANTS AND ANIMALS FOUND IN STUDY AREAS

Common Name	Scientific Name
Plants	
white spruce	*Picea glauca*
black spruce	*Picea mariana*
paper birch	*Betula papyrifera*
aspen	*Populus tremuloides*
balsam poplar	*Populus balsamifera*
willow	*Salix spp.*
Bebb willow	*Salix depressa*
diamond leaf willow	*Salix pulchra*
prickly rose	*Rosa acicularis*
devil's club	*Echinopanax horridum*
alder	*Alnus spp.*
green alder	*Alnus crispa*
resin birch	*Betula glandulos*
dwarf Arctic birch	*Betula mana*
soapberry	*Shepherdia canadensis*
highbrush cranberry	*Viburnum edule*
Labrador tea	*Ledum palustre*
blueberry	*Vaccinium spp.*
bog blueberry	*Vaccinium caespitosum*
cranberry	*Oxycoccus microcarpus*
raspberry	*Rubus idaeus*
spirea	*Spiraea beauverdiana*
crowberry	*Empetrum nigrum*
cloudberry	*Rubus chamaemorus*
twinflower	*Linnaea borealis*
bunchberry	*Cornus canadensis*
wintergreen	*Pyrola spp.*
horsetail	*Equisetum spp.*
fireweed	*Epilobium spp.*
reedgrass	*Calamagrostis spp.*
bluejoint grass	*Calamagrostis canadensis*
sedges	*Carex spp; Eriophorum spp; and others*
bluebell	*Mertensia paniculata*
sandwort	*Moehringia lateriflora*
bedstram	*Galium spp.*
tussock cottongrass	*Eriophorum spp.*
lichens	*Cladonia ssp.; cladina ssp.; and others*
mosses	*Sphagnum spp. and others*

Common Name	Scientific Name
Birds	
common loon	Gavia immer
Arctic loon	Gavia arctica
red-throated loon	Gavia stellata
red-necked grebe	Podiceps grisegena
horned grebe	Prodiceps auritus
whistling swan	Olor columbianus
trumpeter swan	Olor buccinator
Canada goose	Branta cnadensis
white-fronted goose	Anser albifrons
snow goose	Chen caerulescens
mallard	Anas platyrhyncos
gadwall	Anas strepera
pintail	Anas acuta
green-winged teal	Anas crecca
blue-winged teal	Anas discors
cinnamon teal*	Anas cyanoptera
widgeon	Anas americana
shoveler	Anas clypeata
redhead	Athya americana
ring-necked duck	Athya collaris
canvasback	Athya valisineria
greater scaup	Athya marila
lesser scaup	Athya affinis
common goldeneye	Bucephala clangula
Barrow's goldeneye	Bucephala islandica
bufflehead	Bucephala albeola
oldsquaw	Clangula hyemalis
harlequin	Histrionicus histrionicus
white-winged scoter	Melanitta deglandi
surf scoter	Melanitta perspicillata
ruddy duck*	Oxyura jamaicensis
common mergaser	Mergus merganser
red-breasted merganser	Mergus serrator
goshawk	Accipiter gentilis
sharp-shinned hawk	Accipiter striatus
red-tailed hawk	Buteo jamaicensis
Swainson's hawk	Buteo swainsoni
rough-legged hawk	Buteo lagopus
golden eagle	Aquila chrysaetos
bald eagle	haliaeetus leucocephalus
marsh hawk	Circus cyaneus
ospry	Pandion haliaetus
gyrfalcon	Falco rsticolus
peregrine falcon	Falco pereginus
merlin	Falco columbarius

Common Name	Scientific Name
kestrel	Falco sparverius
spruce grouse	Canachites canadensis
ruffed grouse	Bonasa umbellus
willow ptarmigan	Lagopus lagopus
rock ptarmigan	Lagopus mutus
white-tailed ptarmigan	Lagopus leucurus
sharp-tailed grouse	Pedioecetes phasianellus
sandhill crane	Grus canadensis
sora rail*	Prozana carolina
coot*	Fulica americana
semipalmated plover	Charadrius semipalmatus
killdeer	Charadrius vociferus
golden plover	Pluvialis dominca
black-bellied plover	Pluvialis squatarola
surfbird	Aphriza virgata
ruddy turnstone	Arenaria interpres
black turnstone	Arenaria melanocephala
common snipe	Gallinago gallinago
whimbrel	Numenius phaeopus
upland sandpiper	Bartramia longicauda
spotted sandpiper	Actitis maularia
wandering tattler	Heroscelus incanus
willet*	Catoptrophorus semipalmatus
lesser yellowlegs	Tringa flavipes
greater yellowlegs	Tringa melanoleuca
pectoral sandpiper	Calidris melanotos
white-rumped sandpiper*	Calidris fuscicollis
Baird's sandpiper	Calindris bairdii
least sandpiper	Calidris minutilla
dunlin	Calidris alpina
long-billed dowitcher	Limnodromus scolopaceus
semipalmated sandpiper	Calidris pusilla
western sandpiper	Calidris mauri
Hudsonian godwit*	Limosa haemastica
sanderling	Claidris alba
Wilson's phalarope	Phalaropus tricolor
northern phalarope	Phalaropus lobatus
long-tailed jaeger	Stercorarius longicaudus
glaucus gull	Larus hyperboreus
herring gull	Larus argentatus
mew gull	Larus canus
Bonaparte's gull	Larus philadelphia
Arctic tern	Sterna paradisaea
rock dove	Columba livia
great horned owl	Bubo virginaianus
snowy owl	Nyctea scandiaca
hawk owl	Surnia ulula
great gray owl	Strix nebulosa
short-eared owl	Asio flammeus

Common Name	Scientific Name
boreal owl	Aegolius funereus
common nighthawk*	Chrodeiles minor
rufous hummingbird	Selasphorus rufus
belted kingfisher	Megaceryle alcyon
yellow-shafted flicker	Sphyrapicus varius
hairy woodpecker	Picoides villosus
downy woodpecker	Picoides pubescens
black-backed three-toed woodpecker	Picoides arcticus
northern three-toed woodpecker	Picoides tridactylus
Say's phoebe	Sayornis saya
Traill's flycatcher	Empidonax alnorum
Hammond's flycatcher	Empidonax hammondii
western wood pewee	Contopus sordidulus
olive-sided flycatcher	Nauttallornis borealis
horned lark	Eremophila alpestris
violet-green swallow	Tachycineta thalassima
tree swallow	Iridoprocne bicolor
bank swallow	Riparia riparia
barn swallow*	Hirundo rustica
cliff swallow	Petrochelidon pyrrhonota
gray jay	Perisoreus canadensis
magpie	Pica pica
raven	Corvus corax
Clark's nutcracker	Nucifraga columbiana
black-capped chickadee	Parus atricapillus
gray-headed chickadee	Parus cinctus
boreal chickadee	Parus hudsonicus
brown creeper	Certhia familiaris
dipper	Cinclus mexicanus
robin	Turdus migratorius
varied thrush	Ixoreus naevius
hermit thrush	Catharus guttatus
Swainson's thrush	Catharus ustulatus
gray-cheeked thrush	Catharus minimus
mountain bluebird*	Sialia currucoides
wheatear	Oenanthe oenanthe
Townsend's solitaire	Mydestes towndesndi
Arctic warbler	Phylloscopus borealis
ruby-crowned kinglet	Regulus calendula
yellow wagtail*	Motacilla flava
water pipit	Anthus spinoletta
Bohemian waxwing	Bombycilla garrulus
shrike	Lanius excubitor
starling*	Sturnus vulgaris
orange-crowned warbler	Vermivora celata
yellow warbler	Dendroica petechia
myrtle warbler	Dendroica coronata
Townsend's warbler*	Denroica townsendi
bay-breasted warbler*	Dendorica castanea

Common Name	Scientific Name
blackpoll warbler	Dendorica straita
northern water thrush	Seiurus noveboracensis
Wilson's warbler	Wilsonia pusilla
American redstart	Setophaga ruticilla
rusty blackbird	Euphagus carolinus
pine grosbeak	Pinicola enucleator
gray-crowned rosy finch	Leucosticte tephrocotis
hoary redpoll	Carduelis hornemanni
common redpoll	Carduelis flammea
pine siskin	Carduelis pinus
white-winged crossbill	Loxia leucoptera
Savannah sparrow	Passerculus sandwichensis
junco	Junco hyemalis
tree sparrow	Spizella arborea
chipping sparrow	Spizella passerina
white-crowned sparrow	Zonotrichia leucophrys
golden-crowned sparrow	Zonotrichia atricapilla
fox sparrow	Passerella iliaca
lincoln's sparrow	Melospiza lincolnii
Lapland longspur	Calcarius lapponicus
Smith's longspur	Calcarius pictus
snow bunting	Plectrophenax nivalis

Fish

chum salmon	Oncorhynchus keta
coho salmon	Oncorhynchus kisutch
chinook salmon	Oncorhynchus tshawytscha
sockeye salmon	Oncorhy nerka
steelhead trout	Salmo gairdneri
rainbow trout	Salmo gairdneri
arctic grayling	Thymallus arcticus
northern pike	Esox lucius
burbot	Lota lota
arctic char/Dolly Varden	Salvelinus alpinus/Salvelinus malma
lake trout	Salvelinus namaycush
humpback whitefish	Coregonus pidschian
round whitefish	Prosopium cylindraceum
sheefish (inconnu)	Stenodus leucichthys

Mammals

snowshoe hare	Lepus americanus
woodchuck	Marmota monax
Alaska Marmot	Marmota broweri
hoary marmot	Marmota caligata
arctic ground squirrel	Spermophilus parryii
red squirrel	Tamiasciurus hudsonicus
northern flying squirrel	Glaucomys sabrinus
beaver	Castor canadensis
northern red-backed vole	Clethrionomys rutilus
meadow vole	Microtus pennsylvanicus
tundra nole	Microtus oeconomus
yellow-cheeked vole	Microtus xanthognathus
long-tailed vole	Microtus longicaudus
singing vole	Microtus miurus
muskrat	Ondatra zibethicus
brown lemming	Lemmus sibiricus
northern bog lemming	Synaptomys borealis
collared lemming	Dicrostonyx torguatus
Norway rat	Rattus norvegicus
house mouse	Mus musculus
meadow jumping mouse	Zapus hudsonicus
porcupine	Erethizon dorsatum
coyote	Canis latrans

Common Name	Scientific Name
gray wolf	Canis lupus
red fox	Vulpes vulpes
black bear	Ursus americanus
grizzly bear	Ursus arctos
marten	Martes americana
ermine	Mustela erminea
least weasel	Mustela nivalis
mink	Mustela vison
wolverine	Gulo gulo
river otter	Lutra canadensis
lynx	Lynx canadensis
moose	Alces alces
caribou	Rangifer tarandus
Dall's sheep	Ovic dalli

Sources: Gabrielson and Lincoln (1959); Kessel and Gibson (1978); Yocum (1963); Sage (1975).

*Rarely seen in Alaska

Appendix F

CLIMATOLOGICAL DATA

Appendix F

CLIMATOLOGICAL DATA

	Glennallen	Gulkana	Indian Creek	Paxson East	Tok	Anchorage
Elevation, ft.	1650	2000	2600	3900	1650	132
Temperature, ^{o}F						
mean winter max.	6	6	-1	19	-6	27
mean winter min.	-12	-12	-19	7	-23	12
extreme min.	-61	-60	-57	-47	-71	-43
mean summer max.	63	63	60	57	64	57
mean summer min.	41	41	38	45	41	43
Humidity, %						
mean winter	79	79	75	84	87	72
mean summer	64	64	65	73	69	63
Wind						
Prevailing winter direction	N	N	WNW	NNE	NW	NNE
Prevailing summer direction	S	S	WSW	NNE	WNW	WNW
Average winter speed, kn	3	3	7	10	2	4
Average summer speed, kn	5	5	8	11	5	4
Precipitation, in.						
Mean annual	10.2	10.9	16.1	19.4	9.8	15.5
Maximum snow accumulation	44	55	50	58	60	46

Sources: USAF Environmental Technical Applications Center, 1982; USAF Staff Meteorologists, 1985.

Appendix G

KNOWN CULTURAL RESOURCES SITES IN AND NEAR THE STUDY AREAS

Appendix G

KNOWN CULTURAL RESOURCES SITES IN AND NEAR STUDY AREAS

Site No.	Name	Period[a]	Distance From Study Area (mi)	Description
GLENNALLEN STUDY AREA				
GUL 034	Kutarilade (DeLaguna #89)	E	0	Reported Ahtna campsite
GUL 033	Qestcirinene (DeLaguna #88)	E	3.5	Reported Tcicyu clan Ahtna village with 61 feature areas
GUL 093	RCA Station	P	4.1	Flake scatter
GUL 035	Nqalbene (DeLaguna #90)	E	4.6	Reported Ahtna campsite
GUL 032	Tatqana (Ewan Home)	E	6.9	Reported home/temporary camp of Chief Ewan
GUL 087		E?,H	8.0	Two graves and possible wood from a grave house
GUL 085		P?,E?	8.1	Three to four house pits and three cache pits
GUL 084		E,H	8.2	Graves, rectangular depressions, and cache pits
GUL 086		P?,E?	8.5	Three-meter square depression and possible cache pit
GUL 083		P?,E?	10.2	Series of three cache pits

Site No.	Name	Period[a]	Distance From Study Area (mi)	Description
GULKANA STUDY AREA				
GUL 012	Gakona Village	E	0	Ahtna village site
GUL 065	Gakona Roadhouse	H	0	Roadhouse originally developed 1902. New lodges built in 1905 and 1926
GUL 091		E	0	Seven to 10 graves with Russian Orthodox crosses
GUL 057	Gene Cemeteries	H	1.2	Two cemetery complexes
GUL 094	Gulkana Weir	P?,E	1.2	Poss. Ahtna summer camp; house depression, hearths, FCRs, and faunal remains
GUL 015	Talsoker're'	E	1.0	Reported small Ahtna settlement (Possibly noted by Allen in 1885)
GUL 066	Tolsona Roadhouse	H	1.3	Roadhouse along Valdez-Eagle Trail built ca. 1910
GUL 014	Tcitelkere	E	1.6	Reported fish camp belonging to Chief Nicolai
GUL 013	Tazanota	E,P?	1.8	Reported former Ahtna village site
GUL 069	Poplar Grove Roadhouse	H	2.3	Roadhouse/two cabins on Valdez-Fairbanks Trail built 1904-1906
GUL 011	Gulkana Village	E	2.3	Seasonal fish camp and village site
GUL 042	Gulkana Roadhouse	H	2.3	Roadhouse 1904-1948 with trading post. Destroyed by fire
GUL 096	Charlie Ewan Cabin	E?,H	2.9	Collapsed log cabin with sod roof; graves and grave depressions

Site No.	Name	Period[a]	Distance From Study Area (mi)	Description
GUL 077	Ringling (DeLaguna #58)	E,P	3.0	Former Ahtna campsite with 54 feature locations, tested 1975-76
GUL 016	Tsotsaina	E	3.4	Reported former Ahtna settlement
GUL 018	Copper River #1	E	4.4	Former Ahtna settlement
GUL 080	Gulkana River #1	P	4.8	House pit depression and cache pit
GUL 017	Tsidikere	E	5.0	Former Ahtna settlement
GUL 019	DeLaguna #66	E	13.0	Former Ahtna settlement
INDIAN CREEK STUDY AREA				
GUL 028	Qegidadli'na' (DeLaguna #75)	E,P?	1.3	Ahtna village with late-1800s log houses. Identified by Rainey
GUL 089	Jack Craig	E,H	1.5	Complex including collapsed log cabin, cache pits, and housepit and midden
GUL 088	DeLaguna #83	E	2.0	Reported former large Ahtna village site
GUL 029	Tsudrana	E,H	2.7	Camp of four Ahtnas reported by Allen in 1885
GUL 027	Tsabeyna (DeLaguna #74)	E	5.7	Reported former Ahtna village site
GUL 026	Fish Camp Village (Delaguna #73)	E	6.4	Former Ahtna village site of 6 houses occupied up to 1906

Site No.	Name	Period[a]	Distance From Study Area (mi)	Description
GUL 024	Qeyax (DeLaguna #71)	E,H	6.8	Recent (1950) Ahtna fish camp, possibly on older campsite
GUL 025	Tcidrazikere (DeLaguna #72)	E	6.8	Reported former Ahtna village site
GUL 023	DeLaguna #70	E	7.6	Former village of moss houses
GUL 022	Cholcharney House (DL #69)	E	8.0	Ahtna camp reported by Allen in 1885
GUL 067	Sinona Lodge	H	8.6	Historic roadhouse
GUL 021	Snukere (DeLaguna #68)	E	10.1	Reported former Ahtna village site
GUL 020	Qatnaayikere	H	10.2	Campsite of Allen party, May 22, 1885
GUL 044	Chistochina Roadhouse	H	10.4	Roadhouse and Signal Corps telegraph station. In operation 1914
GUL 068	Cobb Lake Roadhouse	H	11.8	Roadhouse on Valdez-Eagle Trail operating in 1914
PAXSON EAST STUDY AREA				
XMH 227	Fish Creek	P	0	Excavated site complex with Denali complex burins, points, cores, and flakes
XMH 219	Timberline Roadhouse	H	2.4	Remains of cabins and two tent structures ca. 1906
XMH 221	Gunnysack Creek	P	2.6	Lithic surface scatter

Site No.	Name	Period[a]	Distance From Study Area (mi)	Description
XMH 218	Paxson's Roadhouse	H	3.8	Roadhouse and telegraph station built ca. 1907
XMH 220	Yost's Roadhouse	H	5.0	Remant of log roadhouse Complex ca. 1906
XMH 255	Fielding Lake Cabin	H	7.2	Standing log cabin ca. 1925
XMH 321	Fielding Lake Overlook	P	7.2	Blowout containing waste flakes
	Tangle Lakes Archeological District	P	10.0	Over 200 prehistoric sites ranging in date from recent to over 10,000 years ago.
TOK STUDY AREA				
TNX 026	Tanana Bridge Quarry	P	0	Microblade and biface fragments, waste flakes, and faunal remains
TNX 027		P	0	Three basalt flakes in paleosol in roadcut
TNX 025		P	4.5	Chert waste flakes and associated charcoal
TNX 006		P	6.0	Small flake scatter (partially destroyed)
TNX 007		P	6.0	Several flakes including obsidian
TNX 008		P	6.0	Small surface flake scatter (destroyed)
TNX 009		P	6.0	Small surface flake scatter (destroyed)

Site No.	Name	Period[a]	Distance From Study Area (mi)	Description
TNX 010		P	6.0	Small surface flake scatter (partially destroyed)
TNX 023		P	6.0	Flake scatter with micro-blades and bifaces; (destroyed)

[a]The following symbols are used to identify different periods: P = prehistoric; E = ethnohistoric; H = historic.

Appendix H

STANDARD ARCTIC CONSTRUCTION PRACTICES

Appendix H

STANDARD ARCTIC CONSTRUCTION PRACTICES

- Construction scheduling in environmentally acceptable windows.
- Winter construction for civil activities, including road construction, excavation, borrow excavation, pile drilling/driving, etc., to minimize surface damage to tundra and and sensitive environments. Winter civil construction can include the use of temporary roads or pads of snow or ice. Thermal syphon piles may be installed to achieve maximum freezeback and to minimize thermal disturbance to permafrost.
- Board insulation may be incorporated into road or foundation systems to minimize borrow quantities and to provide the required thermal protection.
- Steel "H"-type, pipe, or thermal piles or wooden post pilings may be used as primary foundations for large, heated structures as dictated by the in situ thermal regime. These piles may be grouted and/or slurried in place and embedded to minimize frost jacking. Air space is left between building floor and ground to provide ventilation and heat removal. Buildings can also be oriented to avoid snow drifting at entrances or near utilities.
- Utilities, such as water, gas, fuel, electric and wastewater-sewage, can be placed in insulated utilidors. Heat recovery from generating plants can be used to heat these utilidors.
- Properly sized, placed, and thermally protected culverts will be used as required for drainage at low water crossings. Drainage-enhancing geotextile fabrics may be used in poorly drained areas to minimize surface water ponding, thermal erosion, "glaciering," and siltation.
- Borrow, which is frozen and ice-rich, may be stockpiled over a summer season to thaw and drain so that placement and compaction standards can be met to insure structural stability of fill.
- Gravel pads can be constructed, insulated and refrigerated (by active or passive measures) so that slab-on-grade construction can be used.

Appendix I

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Appendix I

DISTRIBUTION LIST

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